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Design and Development of the Instrumentation System for a Greenhouse

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Abstract: Different types of greenhouse systems are used nowadays in the production of crops such as tomatoes, cucumbers, strawberries, carrots, lettuce and pepper. However, the control of the environmental conditions such as temperature, humidity, soil pH and moisture content leads to the improved quality and quantity of the plants. It also enables the growing of the plants all year round regardless of the season. The system also enables the creation of a micro climate that is free from insects; diseases and harsh weather condition from the outside environment hence minimizing the risk of having poor yield of the crops. The control and instrumentation of the system can be attained using sensors and actuators by responding to parameter changes of the environment within the micro climate. Photovoltaic cell is used to utilize solar radiation and use it as an independent source of power.

Keywords: Greenhouse; Control; Instrumentation; Environmental Condition; Photovoltaic;

1. Introduction

A greenhouse is a structure usually made of glass or clear plastic that provides protection and a controlled environment for raising plants indoors [1]. This environment constitutes some parameters such as temperature, humidity, moisture, light intensity and soil pH level that require constant monitoring and control for high quality and yield of the plants [2]. To achieve automatic monitoring and control of the system,, wireless communication using GSM module can be employed from any remote location [3]. The system will serve as shelter that will keep the plants safe from pests, diseases and unfavorable weather conditions. It also helps in minimizing the food shortage caused due to unhealthy season. Sensors can be used to monitor and control the environmental parameters and steady power supply can be achieved solar radiation [4].

2. Literature Review

Many researchers have worked on the development of instrumentation and control systems for greenhouse. [5] carried out a review of greenhouse climate control and automation in tropical regions by examining the methods of instrumentation, control, crop responses and environmental factors in the development of greenhouses. It concluded that, understanding plant responses and environmental factors is key in the design of instrumentation and control strategies. [6], [7] developed control strategies using adaptive fuzzy and fuzzy logic self-tuning techniques for greenhouse micro-climates. The results obtained from the research show that both the temperature and humidity of the greenhouse were controlled to within the specified limits in the presence of disturbances. [8] carried out the construction and development of an adaptive controller for a greenhouse by carrying out system identification to determine the model of the system parameters. The results obtained show that the controllers were able to adjust the controlled parameters to follow the reference model.

Other methods for instrumentation and control of greenhouse based on fuzzy logic control, predictive control and intelligent control techniques were also reported in literature [9]–[11]. Similarly, robust control techniques and PID-based control techniques were employed in the control of environmental parameters in a greenhouse [12], [13]. The review of themal models and heating technologies was also carried out by [14] with a view to highlighting the importance of maintaining optimum thermal conditions in a greenhouse for the production of crops. Several other related works on the use of wireless sensor networks in the development of greenhouses for optimal crop production have also been presented in literature [15], [16].

3. Block Diagram

The block diagram of the system is shown in Figure 1. It is a diagram that shows the main parts of the system and their functions.

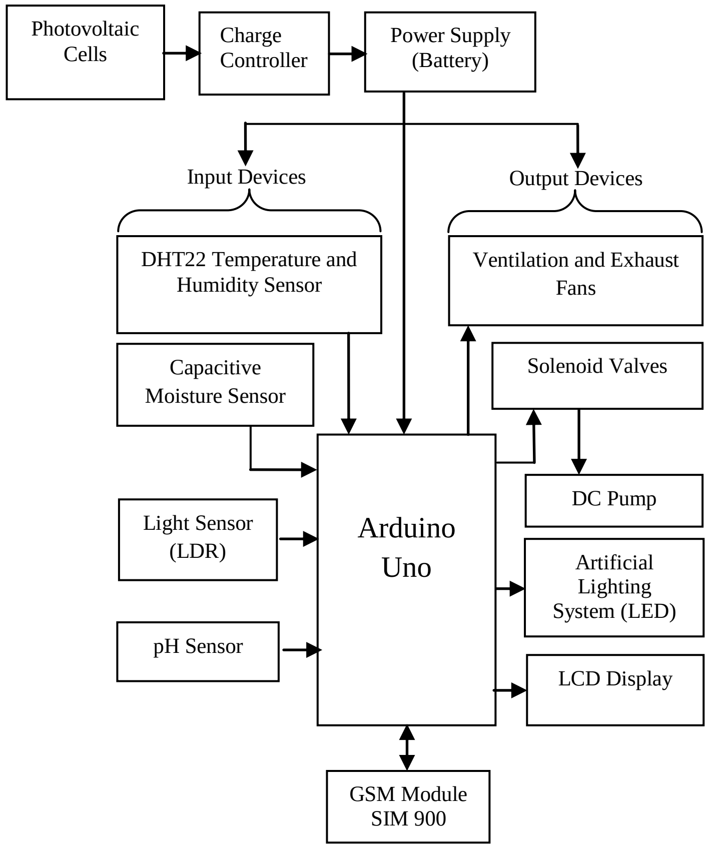

Figure 1: Block Diagram of the Greenhouse

4. Flow Chart

The sequence of functions of the components and mode of signal flow through the greenhouse is shown in the flow chart in Figure 2.

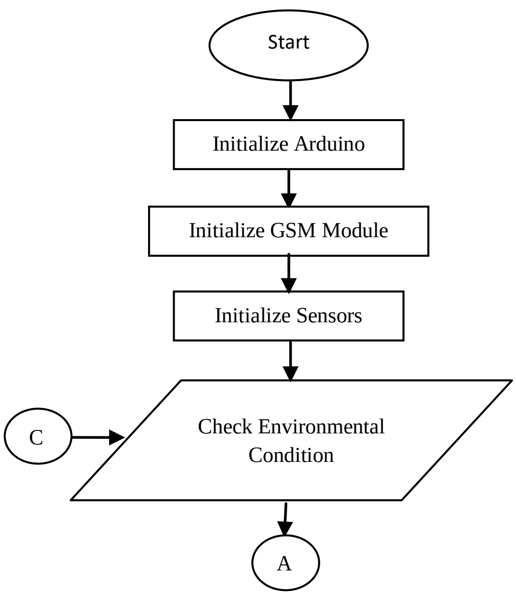

Figure 2 (a)

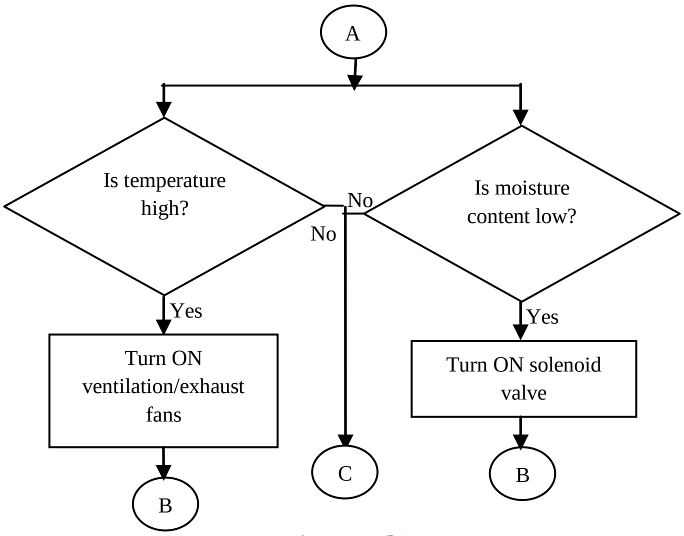

Figure 2(b)

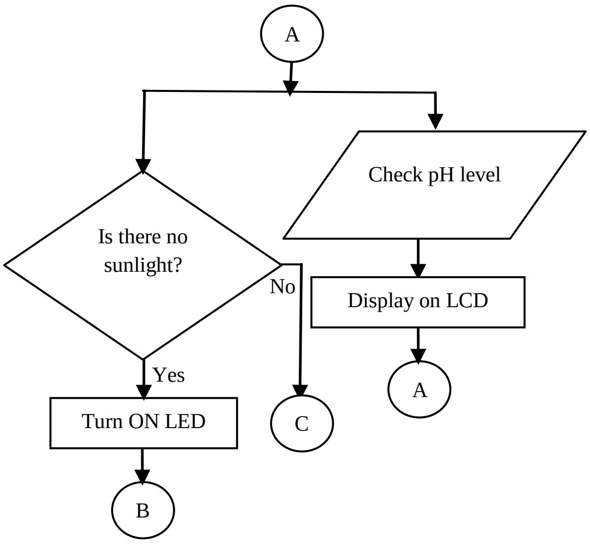

Figure 2(c)

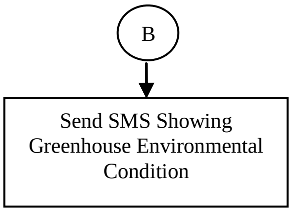

Figure 2(d)

Figure 2: Flow Chart of the Greenhouse

5. List of Materials

The materials adopted in the design and implementation process are;

1. Arduino Uno board with ATMega328p microcontroller
2. SIM 900 GSM Module
3. Solar power supply with batteries
4. DHT 22 Temperature and humidity sensor
5. Capacitive moisture sensor
6. Light Sensor
7. pH Sensor
8. Ventilation and Exhaust Fans
9. Lighting System
10. DC Pump
11. Display Unit
12. Arduino IDE Software
13. Livewire Circuit Design Software
14. Solid Works Software.

5.1 Arduino Board

The Arduino Uno is a single microcontroller circuit development board that provides an easier for the design of electronic circuits. It has a 32 KB flash memory, fourteen digital input/output pins of which six can be used as Pulse Width Modulation (PWM) outputs and six analog input pins. It is used to perform a wide range of operations using the software kit provided with it. It can be used to convert ultrasonic sensor signal into vibrator signal. The main feature of the Arduino board is that programming is easier when compared to the other devices such as the PIC16FX series microcontroller and the circuit size is reduced. Plate I shows a picture of the Arduino Uno board.

Plate I: Arduino Uno with ATMega328p Microcontroller.

5.2 SIM 900 GSM Module

This is a quad-band modem being able to operate in 850, 900, 1800 and 1900 MHz bands that work on GSM networks in all countries across the globe. It offers improved GPRS functionalities useful in web enabled applications and operates from 3.4-4.5V supply range and supports short message service so as to enable the sending of small amounts of data over the network. It has low power consumption, -1.5mA on sleep mode and industrial temperature range of -40°C to +85 °C. Its approximate dimension is 8.5 x 5.7 x 2cm as shown in Plate II.

Plate II: SIM 900 GSM Module

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5.3 DHT22 Temperature and Humidity Sensor

The DHT22 is a commonly used temperature and humidity sensor. It comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data to the nearest tenth (i.e to one decimal place). The sensor is factory calibrated hence easy to interface with other microcontrollers. It has an operating voltage of 3-5V, maximum operating current of 2.5-0.3mA and a sampling rate of 0.5Hz reading every 2s can measure temperature from -40°C to 80°C and humidity from 0% to 100% with an accuracy of ±0.5°C and ±2-5% respectively.. Its resolution: temperature and humidity are both 16-bit. The sensor has a body size of 15.1 x 25 x 7.7mm. Its picture is shown in Plate III

Plate III: DHT22 Temperature and Humidity Sensor

5.4 Capacitive Moisture Sensor

This is a small capacitor consisting of a hygroscopic dielectric material placed between a pair of electrodes. At equilibrium, the amount of moisture present in a hygroscopic material depends on both ambient temperature and ambient water vapor pressure. The sensor determines the amount of soil moisture by measuring changes in capacitance to determine the soil water content. This can be used in an automatic plant watering system, as the case with this work, or to signal an alert of some type when a plant needs watering. The sensor has analog output of moisture content, is highly resistant to corrosion, than resistive type of sensor and has a voltage range of 3.3-5V. Plate IV shows a picture of the capacitive moisture sensor.

Plate IV: **Capacitive Moisture Sensor**

5.5 Light Sensor

A typical **l**ight sensing circuit uses the light dependent resistor **(**LDR**),** which is a resistive light sensor, for switching ON-OFF of the system with respect to the intensity of light that falls on it. The LDR, also known as photo resistor, has its resistance changing with variation of photons falling on it. They are mostly made by using a Cadmium Sulfide (CdS) which is a semiconductor material. As shown in the Plate V, LDR is a two terminal device with zig-zag trails from one end to another with an isolation layer above and CdS below.

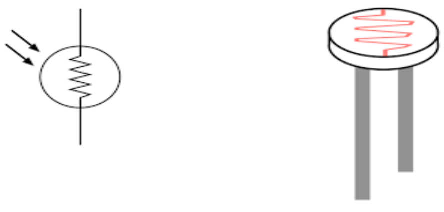

Plate V: Light Sensor

5.6 Ventilation and Exhaust Fans

The greenhouse system needs constant flow of air to keep the temperature in the structure conducive for optimum plant growth. This can be achieved using ventilation (inlet) and exhaust (outlet) fans.

5.6.1 Ventilation Fans

These are fans used to ventilate a residential or commercial space. It works to bring fresh air from the outside and circulate it through an enclosed building, such as the greenhouse, thereby keeping the temperature within the building favorable and relatively low.

5.6.2 Exhaust Fans

Unlike the ventilation fan, when pollutants and contaminants enter the air, exhaust fans remove them in order to provide clean air. Some common contaminants and pollutants include smoke, moisture, dust, and unpleasant odors can efficiently be removed from the greenhouse building using the exhaust fan.

5.6.3 Differences between these Fans

Though both ventilation and exhaust fans work to ensure optimum temperature in the space in which they are installed. The main difference between them is their application. While a ventilation fan works to bring clean air into an enclosed space from an outside source, an exhaust fan removes pollutants from the indoor air in the space under consideration. Each fan has unique characteristics that allow it to perform its intended actions efficiently. Also, ventilation fans are normally installed at lower positions of the building because cool air is denser and hence move at lower altitudes while exhaust fans are placed at relatively higher positions so as to suck away the less dense warmer air from the greenhouse structure, which moves at higher altitudes. The pictures of ventilation and exhaust fans are shown in Plates VI (a) and VI (b) respectively.

Plate VI (a): Ventilation Fan **Plate VI (b)**: Exhaust Fan

5.7 DC Pump

These are motors powered by direct current from motor, battery or solar power to move fluid in a number of ways. Motorized pumps typically operate on 6, 12, 24, or 32 volts of DC power. Solar-powered DC pumps use photovoltaic (PV) panels with solar cells that produce direct current when exposed to sunlight. As with most pumps, the primary features to consider when selecting DC powered pump performance are the flowrate, pump head, pressure, power rating and operating temperature. For this research, a 12 V, 5A, 1300rpm DC motor will be used. A typical DC pump is shown in Plate VII.

Plate VII: DC Pump

5.8 pH Sensor

The pH is a measure of soil acidity or alkalinity. Plants require a suitable environment condition to grow and produce high and quality yield. The soil pH level is among these conditions. The pH scale is labeled 0-14, from 0-6.9 is acidic, 7.0 is neutral and 7.1-14 is alkaline. The optimum soil pH range for tomatoes, and hence most vegetables, is 5.8 - 6.8 (slightly acidic). Soils below 5.9 should be limed to raise the pH and to supply the necessary calcium tomatoes need. Regular agricultural lime, if needed, should be broadcast over the greenhouse soil and worked in at least several weeks before planting. A pH sensor is commonly used for measuring this soil pH level. A typical pH sensor is shown in Plate VIII

Plate VIII: **pH Sensor**

6. Expected Results

At the end of this research, a prototype greenhouse with dimensions 3 metre length by 2 metre width by 3 metre height will be constructed. The greenhouse will have sensors and actuators installed in it so as to have full automation as regards the sensing of parameter changes as well as switching of the corresponding actuators to respond to these changes and ensure optimal condition for the plant (tomatoes in this case). These parameters include temperature and humidity of the surrounding environment, light intensity, pH level and moisture of the soil. The structure will be formed using galvanized noncorrosive iron with trapezoidal symmetrical cross-section. It will be covered with transparent polythene material as shown in the greenhouse structure in Plate IX.

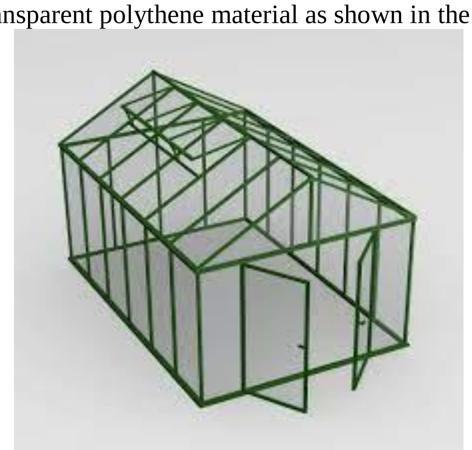

Plate IX: Greenhouse Structure

References

[1] P. H. Patil, C, Borse, S. Gaikwad, and S. Patil, "Greenhouse Monitoring System using GSM," International Journal of Science and Engineering Research, IV (6), pp. 7169-1777. 2013.

[2] A. K. Chauhan and P. K. Gupta "Intelligent Greenhouse Environment Monitoring and Automatic Controlling System using IoT," International Journal of Recent Technology and Engineering, VII (6), pp. 45-49, 2019,

[3] A. Hanggoro, R. Reynaldo, M. A. Putra, and R. F. Sari, "Greenhouse Monitoring and Controlling Using Android Mobile Application," IEEE Conference Publications,

[4] P. Karthikeyan, E. Mohanraj, p. Prabhu, and C. Dinesh, "Design and Analysis of Solar Powered Automated Green House," International Journal of Theoretical and Applied Mechanics. XII (4), pp. 821-827, 2017,

[5] R. Shamshiri, "A Review of Greenhouse Climate Control and Automation Systems in Tropical Regions" Journal of Agricultural Scienc and Application. II (3), pp. 175–183, 2013.

[6] S. Amar and S. Amar, "Adaptive Fuzzy Control Strategy for Greenhouse Micro-Climate" International Journal of Automation and Control, XXII (1), pp. 108–125, 2018.

[7] M. Heidari and H. Khodadadi, "Climate Control of an Agricultural Greenhouse by using Fuzzy Logic Self Tuning PID Approach". In Proceedings of the IEEE International Conference on Automation and Computating Addressing Global Challenges through Automation and Computating (ICAC), pp. 7-18, 2017,.

[8] L. Wang and B. Wang, "Construction of Greenhouse Environment Temperature Adaptive Model Based on Parameter Identification," Computers and. Electronics in Agriculture., CLXXIV (1). pp. 105-117.

[9] Y. Su, L. Xu, and E. D. Goodman, "Greenhouse Climate Fuzzy Adaptive Control Considering Energy Saving," International Journal of Control and Automation and Systems, XV (4), pp. 1936–1948, 2017,

[10] D. Lin, L. Zhang, and X. Xia, "Hierarchical Model Predictive Control of Venlo-type Greenhouse Climate for Improving Energy Efficiency and Reducing Operating Cost," Journal of Cleaner Production, CCLXIV

(5), pp. 121-133, 2020.

[11] J. Riahi, S. Vergura, D. Mezghani and A. Mami, "Intelligent Control of the Microclimate of An Agricultural Greenhouse Powered by A Supporting PV System," Applied Science, X(4), 2020,

[12] K. Lammari, F. Bounaama, and B. Draoui, "Interior Climate Control of Mimo Green House Model using PI and IP Controllers," ARPN Journal of Engineering and Applied Science, XI(21), pp. 6039–6046, 2017.

[13] L. Chen, S. Du, Y. He, M. Liang, and D. Xu, "Robust Model Predictive Control for Greenhouse Temperature Based on Particle Swarm Optimization," Information Processing in Agriculture, V(3), pp. 329–338, 2018.

[14] V. P. Sethi, K. Sumathy, C. Lee and D. S. Pal, "Thermal Modeling Aspects of Solar Greenhouse Microclimate Control: A Review on Heating Technologies," Solar Energy, XCVI (5), pp. 56–82, 2013,

[15] C. Akshay et al., "Wireless Sensing and Control for Precision Green House Management," In Proceedings of International Conference for Sensing Technology ICST, pp. 52–56, 2012,

[16] K. P. Ferentinos, N. Katsoulas, A. Tzounis, T. Bartzanas, and C. Kittas, "Wireless Sensor Networks for Greenhouse Climate and Plant Condition Assessment," Biosystem Engineering., CLIII (7), pp. 70–81, 2017.