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Design and Implementation of a Smart Greenhouse Automated and Conditioned by Solar Power System

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HIGHLIGHTS

- Photosynthesis requires additional energy, which can be obtained by building a greenhouse that traps sunlight's heat.
- The primary challenge in greenhouse growing is stabilizing temperature swings.
- The greenhouse control systems have been adapted and implemented to meet the demands of plant cultivation.

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ABSTRACT

Photosynthesis requires additional energy. Such energy can be obtained by building a greenhouse, which traps sunlight's heat. The primary challenge in greenhouse growing is stabilizing temperature swings. Adapting conventional heating and cooling systems can provide additional energy to the greenhouse. In the greenhouse, solar energy is a vital energy source that is directly connected to the power supply. The greenhouse control systems have been adapted and implemented to meet the demands of plant cultivation due to wireless automation, design, control, and monitoring services. This study provides an effective automation system for greenhouses. It lowers the power, leads to consumption, and allows for remote control and monitoring. They show that the control model monitors sensing data are an accurate tool for computing sensing and the self-management of output devices. It was also found that this technology has several positive attributes such as easy network management and motor controls, soil moisture, humidity, temperature, and sensor to solar panel voltage. It measures the four sensors included in the suggested design system. Each sensor measures changes in the environment inside the greenhouse. All sensors are accessible in varied ratios to run devices plugged for different operations because irrigation, refrigeration, and air conditioning always start when depletion occurs.

1. Introduction

A greenhouse is a space enclosed in a transparent frame with a partial or complete control system to achieve optimal crop production parameters. The greenhouse effect involves retaining heat by the light-permeable wall, which increases the temperature inside by letting in sunlight but also increases humidity. Agriculture and crop development technology have advanced significantly over the past few decades. However, due to the uneven natural distribution of rainwater, farmers should monitor the equitable distribution of water to all crops according to the requirements.

No ideal irrigation method is suitable for all weather conditions and soil structures. Greenhouse technology may be the best approach. Farmers in many countries tend to use greenhouses outdoors to increase production. However, greenhouse is a high energy-intensive and fossil-fuel-intensive agricultural method that contributes significantly to greenhouse gas (GHG) emissions. One of the most practical ways to solve this problem and replace traditional energy sources with renewable energy is to use energy-saving strategies. In recent years, the ability to integrate solar energy with greenhouses has been established. This paper examines the development of photovoltaic agriculture.

Most previous researchers found that growing plants in a greenhouse is one of the best options if several conditions are available. A good and successful greenhouse aims to provide plants with ideal weather conditions [1]. Technological advances in wireless sensor networks have made it possible to use greenhouse properties for accurate agricultural tracking and monitoring. It has been done this way for a long time using greenhouse construction. Therefore, the greenhouse must have high light transmission, adequate and efficient ventilation, a robust structure, low operating costs, and good quality of trapping most of the heat. However, for the greenhouse to be as efficient as possible, additional energy must be added. However, it comes at a higher price than the standard method. Lower production costs can be achieved using sustainable energy sources [2].

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As a result of effective heating in the winter, summer crops can be grown. In heating the greenhouse, two methods were used, one passive and the other active. In the passive heating method, water is stored in a bedrock. In addition, there are insulated walls, movable insulation, and a thermal screen. As for the method of active heating, the solar panels, ground collectors, geothermal heat pumps, and heat exchangers are coupled with the ground as external energy sources. Active technology is utilized in many types of research [3, 4].

Energy from the sun can be harnessed as light or heat, depending on use. There have been various uses of solar energy throughout history. Since then, research has led to the development of new technologies that can be used in areas that are colder and cloudier today [5-7]. A huge amount of electricity is needed in hot and dry places like Baghdad (33°N and 45°E). In addition, alternative energy is needed in the face of the global threat of depleting fossil fuels. The smart greenhouse in Baghdad must be powered by solar energy to meet these two requirements [8-11]. Diverse uses of solar energy have been made throughout history. Since then, research has led to the development of new technologies that can be used in considerably colder and cloudier regions today [2, 12-14]. Baghdad's cold and dry climate makes greenhouse technology a viable alternative.

This paper presents a method of controlling greenhouses to control the temperature and humidity inside the greenhouse and reduce the consumption of electrical energy. This can increase and improve efficiency and is a clean and reliable power source. However, plants inside the greenhouse are exposed to several factors that can affect their growth or density, which leads to a decrease in agricultural production. Therefore, the purpose of this paper is to study the effect of a smart control system for the greenhouse to control the temperature and humidity inside the greenhouse, such as the traditional cooling system and ventilation system. These systems provide data monitored by the farmer and intelligent control methods for the parts of the greenhouse. The contributions of this paper can be summarized as follows: Controlling all conditions inside the greenhouse and making it suitable for the growth of plants without the need for direct intervention from the farmer. It works to maintain the appropriate temperature inside the greenhouse and the amount of moisture required to promote plant growth and development.

2. Sensors of the Greenhouse

To grow aesthetic and food crops in a greenhouse that can maintain a temperature and promotes plant growth and development [15]. It is neither simple nor inexpensive to maintain the desired temperature. Heat and ventilation in greenhouses consume a lot of energy to maintain desired temperature set points. Soil moisture sensors are available for greenhouse manufacturing and research applications. In greenhouses, such sensors can help to improve the homogeneity of substrate water content and automate irrigation based on plant water consumption. Can improve irrigation system design by quantifying spatial variability. By watering based on real crop water usage, soil moisture sensors have the potential to reduce temporal variability in substrate moisture content dramatically.

3. Arduino UNO kit

Arduino is a kit that uses a microcontroller. A simple board and software development environment are included in this open-source platform. Figure (1) shows the primary structure of Arduino. It comprises an ATmega328-based microcontroller board. An ICSP header, a USB connector, a power jack, and a reset button are among the features of this microcontroller [16].

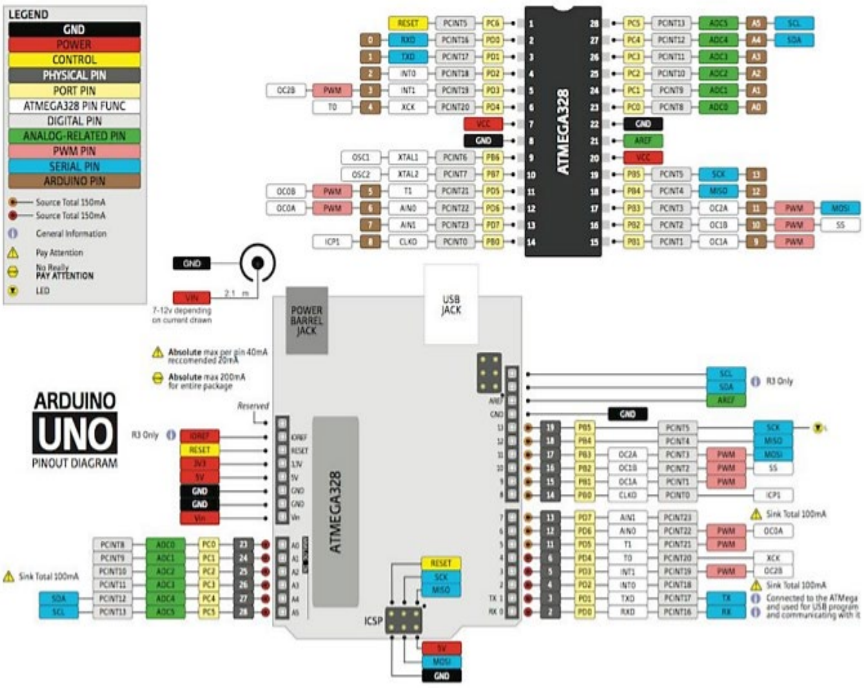

Figure 1: Circuit diagram of the Arduino kit [16]

4. Systems of the Smart Greenhouse

In a smart greenhouse, real-time monitoring of the greenhouse's internal and external context information ensures that the greenhouse interior environment is appropriate for growing crops. Plants grown in a greenhouse are affected by various elements, including soil moisture and climate (temperature, humidity, etc.) [17]. Therefore, researchers were primarily concerned with designing and implementing a system for monitoring climate conditions and managing the various devices on outputs (water pump and fan). Sensors and motors are coupled to a controller circuit (Arduino UNO) for data collection. Figure (2) shows Arduino's connection with the system (sensor and fan).

4.1 Hardware Description

A microcontroller ATMega32 with many inputs and outputs, as well as ADCs and PWM, was used in the hardware design. Go over each of the inputs and outputs used during the design process.

4.1.1 Arduino mega

For storing code, the ATmega2560 contains 256 kilobytes of flash memory (of which 8 kilobytes are required for the bootloader) and 8 kilobytes (which can be read and written with the EEPROM library).

4.1.2 MAX 6675 amplifier

For cold junction correction, the MAX6675 digitizes the Type-K thermocouple signal. A read-only SPITM-compatible format with a 12-bit resolution is used to output the data. There is a 0.25°C resolution and a maximum temperature of +1024°C.

4.1.3 SD card module

As a result of the module's (Micro SD Card Adapter's) ability to read and write to Micro SD cards using the file system and an interface driver for the SPI interface, an SCM system can be.

4.1.4 Soil moisture sensor

Using this soil moisture sensor module, it can be measured by the moisture content of the soil. Determined by measuring how much water is contained in a soil sample. As well as a potentiometer to alter the threshold level, the module contains both digital and analog outputs.

4.1.5 DHT22 digital humidity and temperature sensor

The DHT22 Digital Temperature and Humidity Sensor Module AM2302 is a basic, low-cost digital temperature and humidity sensor. It measures temperature and relative humidity. Capacitive and thermistor sensors provide humidity and temperature readings, which are converted to a digital signal via the data pin (no analog input pins are needed).

4.1.6 Thermocouple type k

ANSI/ASTM E230 or IEC 60584 for Type K thermocouples defines a Type K thermocouple as any temperature sensor with Chromel and Alumel l conductors. These sensors and cables could be an immersion sensor, an external surface sensor, or a wire, among others.

4.1.7 Relay 4 channel

It can be used to regulate high voltage, high current loads such as motors, solenoids, lamps, and AC loads. An interface is provided for Arduino, PIC, and other microcontrollers are also equipped with a status LED [18].

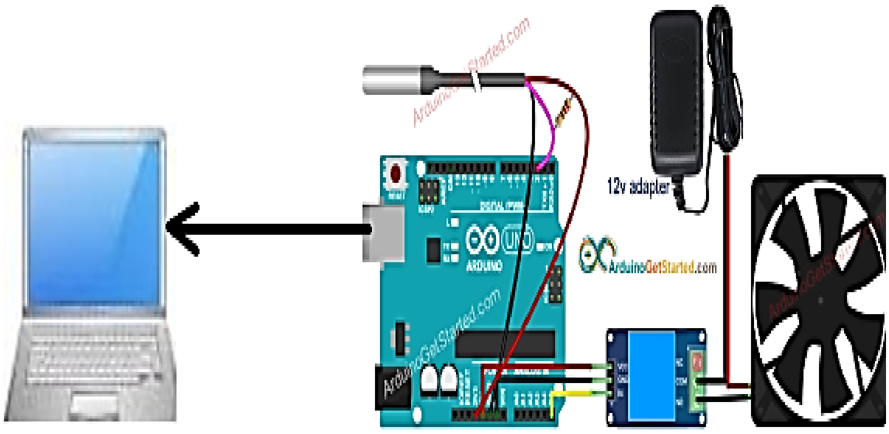

Figure 2: Arduino connection diagram

4.2 System Control Technique

The temperature inside the greenhouse should be between (18°C -25°C) if the temperature rises above 25°C, the ventilation pullers and the cooling system (pump) work automatically. However, if the humidity inside the greenhouse rises above 60%, the ventilation pullers will work only to reduce the humidity.

5. Experimental Procedure

Steps to connect the control system Figure (3) and Figure (4) will show the control system integrated with the greenhouse.

1) Connect relay pins to Arduino pins.
2) Connect the SD card module to Arduino.
3) Connect the max 6675 to Arduino.
4) Connect sensors pins to Arduino & power.
5) Connect loads to relays.
6) Write the Arduino code, and upload it.

To display data from sensors and transmit it to an excel sheet, code was written for the client-side (input interface in Figure (5)) in an Arduino programmer application. To achieve this, an interfaced electronic circuit is used to gather information from numerous sensors. In addition, the monitoring system is designed to save data.

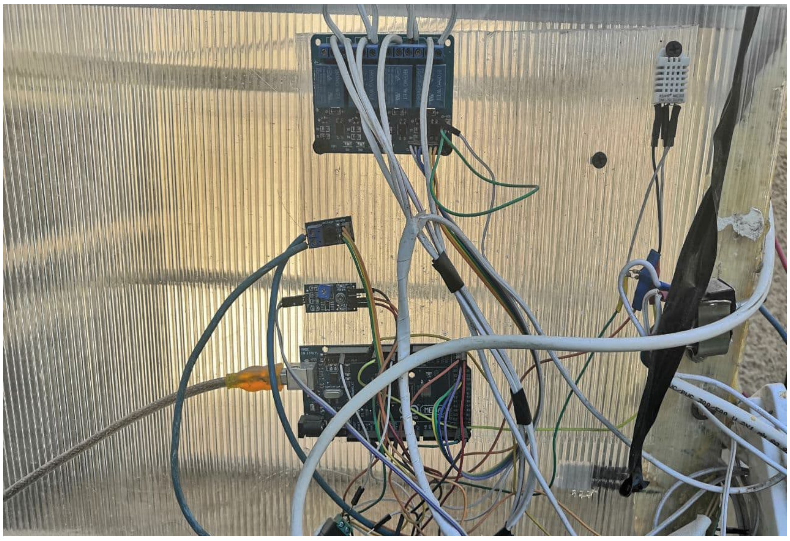

Figure 3: Control system

Figure 4: Control system with the greenhouse

A renewable energy source is a solar energy, one of the various forms of renewable energy sources. Clean and pollution-free, it is a good source of energy. Solar energy can be employed in the smart greenhouse system as an electric or thermal energy source. When it comes to energy, it is the next big thing. This technology plays a crucial role in making the environment greener and cooler. As a result of using a solar-powered greenhouse system, it is possible to care for plants by providing them with illumination and maintaining the temperature that they require in cold climates [19]. The greenhouse design is designed to fit the latitude and longitude of the city of Baghdad. It is the shape (even span) of the structure of aluminum and the walls of polycarbonate that transmits light and has heat preservation properties to maintain heat inside the greenhouse. The solar panel tracking system is a motor (Linear Actuator Putter 300 mm Stroke DC 12V, 1-3A) in Figure (6). An arm is used to raise and lower the panel according to the intensity direction of the solar radiation to a certain angle— the angle of latitude for the city of Baghdad.

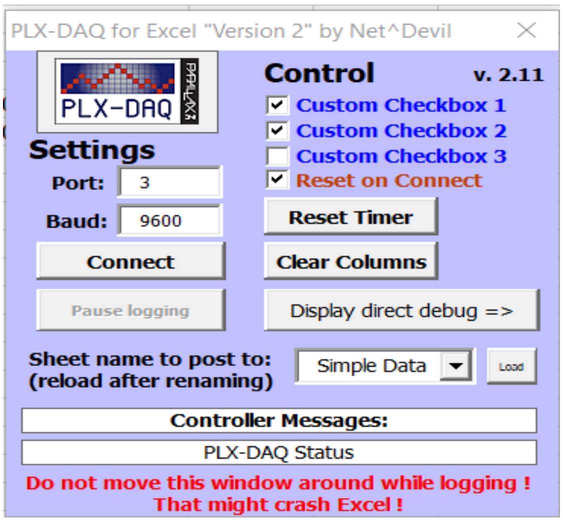

Figure 5: Input interface

Figure 6: Linear Actuator

6. Results and Discussion Database Design for the Server

To publish sensor data and control commands submitted by remote system monitoring, the server design in this paper was utilized to publish the sensors' data. Documents have been delivered by the server (excel sheet). In addition, a spreadsheet was created to upload and retrieve data from the main system monitoring. Data from sensors and solar panel voltage measurement is represented by (eight) different fields in the server configuration, as indicated in Figure (7) below.

The relationship between sensor data and time is shown in the following Figure (8). As a result of the incidence of solar radiation, the plant temperature (Tp) and the injected air temperature (Tr) began to climb from 7:00 a.m. and raise achieved a value that excessed the temperature required. To maintain the proper temperature of the plant, the excess heat energy from the greenhouse enclosure should then be eliminated. Figure 8 shows that the temperature of the outside air throughout the day is often higher than the temperatures inside the greenhouse with the presence of cooling within 3-5°C. Moreover, it was less than the temperature inside the greenhouse without cooling by 2-3°C. A comparison between experimental and theoretical temperatures inside the greenhouse and the plant's temperatures theoretically and experimentally was archived. The present model theoretical can predict greenhouse temperature practical with a mean percentage error of 2%. The experimental greenhouse temperatures show us 2-4°C lower than the theory because the equations neglect the factor of time and continuous cooling inside the greenhouse, as well as because of the accuracy of the measuring devices in which there is a wrong percentage, and the same situation concerning experimental and theoretical plant temperatures. The radiation intensity directly affects the temperature inside the greenhouse, and the relationship between them is direct. The greenhouse is located to capture the maximum possible irradiance. The solar panel is installed at the top of the greenhouse. One of the benefits of the location of the solar panel is that it causes a moderate percentage of shade for the greenhouse. The results of the radiation shown in the curve are the results of the solar radiation falling on the solar panel.

It appears in Figure (9) that the humidity in the climate of Iraq is not high in general, as the humidity inside the greenhouse or outside is very close. However, it is noticed from the curve that the humidity inside the greenhouse is sometimes higher than outside the greenhouse, in the range of 2-6%. This is because the cooling inside the greenhouse depends on the traditional water cooling system.

	A	B	C	D	E	F	G	H
1	temp.outside	temp.inside	humidity inside	humidityoutside	SoilMoisture	SoilTemp	SolarVoltage	PlantTemp.
2	39.9	37	19.7	28.8	87	[illegible]	[illegible]	41.9
3	39.9	37	19.8	27.8	95	[illegible]	[illegible]	41.9
4	39.9	37	19.8	29	96	34	20.57	41.9
5	39.9	37	19.7	29.1	110	34	20.54	41.9
6	39.9	37	20	29.1	110	34	20.57	41.9
7	39.9	37	20.2	29.3	97	34	20.54	41.9
8	39.9	37	20.1	29	91	34	20.57	41.9
9	39.9	37	20	28.9	96	34	20.54	41.9
10	39.9	37	20.4	28.9	110	34	20.54	41.9
11	39.9	37	20.3	28.9	110	34	20.54	41.9
12	39.9	37	20.5	29	105	34	20.52	41.9
13	39.9	37	20.2	29.2	87	34	20.54	41.9
14	39.9	37	20.1	29.2	110	34	20.54	41.9
15	39.9	37	20.2	29.3	89	34	20.52	41.9
16	39.9	37	21	29.6	110	34	20.52	41.9
17	39.9	37	22.3	29.6	86	34	20.52	41.9
18	39.9	37	22.2	29.7	101	34	20.5	41.9
19	39.9	37	22.2	29.9	110	34	20.47	41.9
20	39.9	37	21.9	30.1	110	34	20.5	41.9
21	39.9	37	21.3	30.7	110	34	20.5	41.9
22	39.9	37	21.1	30.4	105	34	20.52	41.9
23	39.9	37	21.1	30.5	107	34	20.5	41.9
24	39.9	36.9	21	30.4	110	33.9	20.5	41.9
25	39.9	37	21	30.3	110	34	20.54	41.9
26	39.8	36.9	20.6	30.1	105	33.9	20.52	41.8
27	39.8	37	20.2	30.1	90	34	20.52	41.8
28	39.8	37	20.8	29.9	105	34	20.5	41.8
29	39.9	37	21.2	29.6	110	34	20.52	41.9
30	39.8	37	20.9	29.3	92	34	20.52	41.8
31	39.8	37	20.4	29	110	34	20.5	41.8
32	39.8	36.9	20	28.8	91	33.9	20.52	41.8
33	39.8	37	19.8	28.8	110	34	20.52	41.8

Figure 7: Spreadsheet design

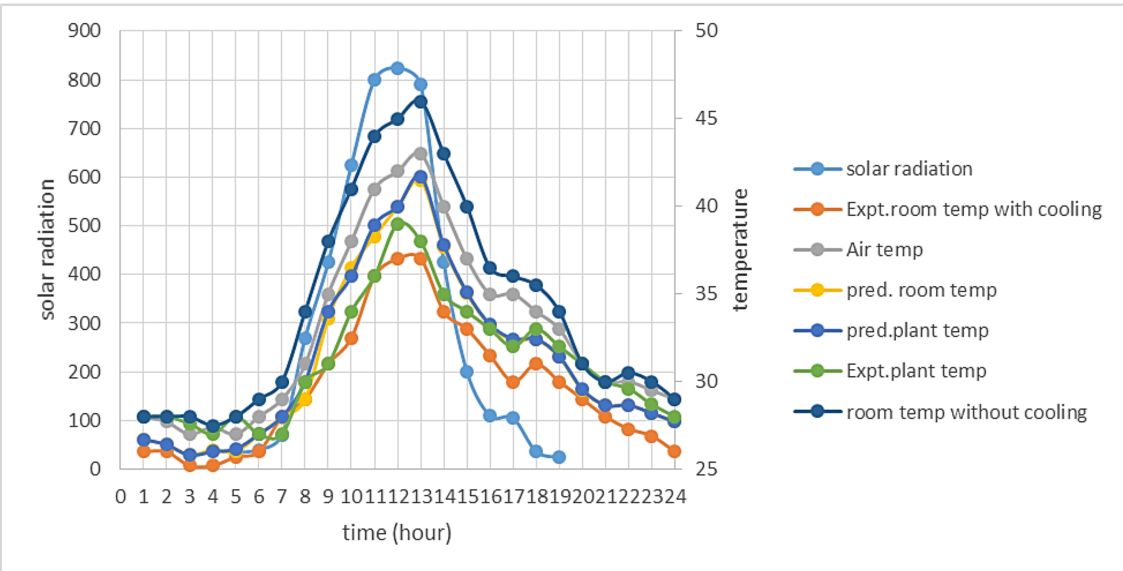

Figure 8: Relationship between temperature sensor with time and solar radiation

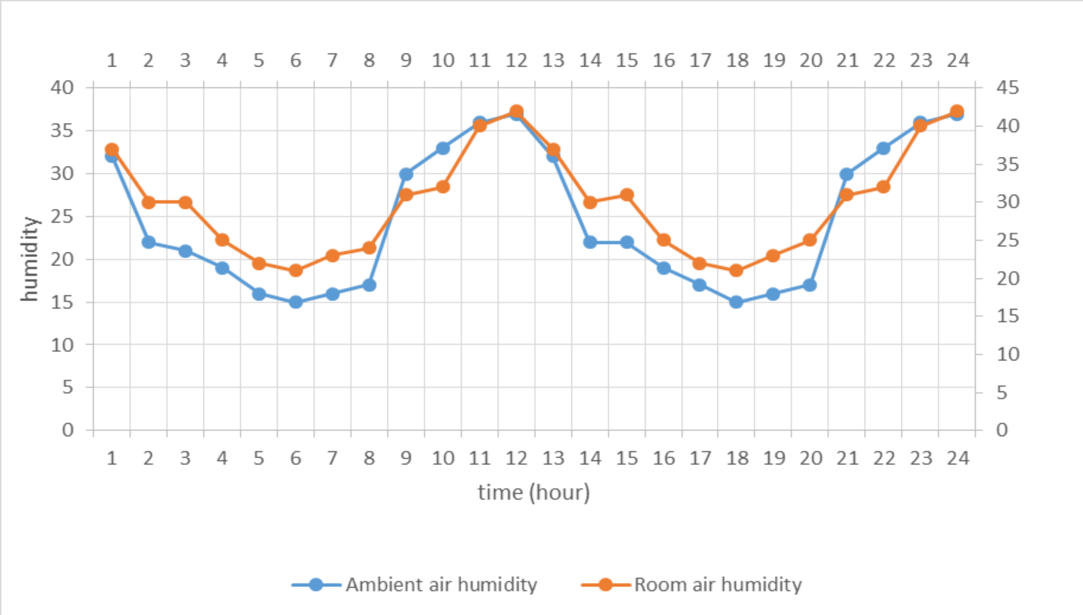

Figure 9: Relationship between humidity sensor with time and solar radiation

7. Conclusion

The greenhouse cultivation system has many advantages, such as ease of growing plants in cold climates and enhancing production, quality, and overall production of products. It is possible to grow plants in cold climates using a smart greenhouse system powered by solar energy sources. This system can provide fertigation, lighting, and temperature control. All of these must be combined and applied on a wide scale to prevent global warming and protect the environment. Smart greenhouses in Iraq can utilize additional renewable. This paper presented the benefit of using the greenhouse control system, as the energy consumption spent on the greenhouse cooling system is reduced at a time when the temperature inside the greenhouse is suitable for plant growth. All sensors are placed to control and make the climatic conditions inside the greenhouse suitable for increasing the agricultural yield. The greenhouse cultivation system has several advantages, the most important of which is the possibility of growing plants in seasons that differ from their seasons. To reduce cost and increase productivity, a complete control system was used for all parts of the greenhouse that performs many operations. These operations include controlling the high temperatures of the greenhouse through the operation of the traditional cooling system automatically and the ventilation system, which also works automatically when the humidity is high. A set of sensors has been placed to measure the temperature and humidity inside and outside the greenhouse.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

Authors declare that their present work has no conflict of interest with other published works.

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