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Design and Implementation of Green House Data Logger for Optimum Crop Production

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ABSTRACT

Greenhouse technology is a viable option for sustainable crop production in regions of adverse climatic conditions. During hot seasons the heat input to a greenhouse causes the internal temperature to exceed its optimal value. The present study was devoted to constructing an evaporative cooling system to reduce heat stress inside a greenhouse. The use of greenhouses with controlled microclimate according to the plant's needs is an important way to increase the production of fruits and vegetables and has recently become one of the hottest topics in precision agriculture. To know and control the greenhouse microclimate, smart sensing nodes with wireless communication capabilities are recommended. This paper presents a review of the use of technologies for automated activities in greenhouses. Different microclimate parameters inside the greenhouse are to be precisely controlled for successful greenhouse cultivation or to maximize production. Controlling can be done either by manually or by an automatic control system which comprises measurement, data processing, recording and management of environmental parameters. The manual method of control is not accurate, very time-consuming and very laborious process. Hence automatic control of microclimate is required for better performance of the greenhouse. Different methods of automation of the greenhouse include the use of microprocessor-based control systems and computer-controlled systems. Computerized control is more accurate but not economical for small and medium farmers. Microprocessor-based control is good for small farmers.

Keywords: Automation, Greenhouse, Microclimate control.

1 INTRODUCTION

A greenhouse is a specially designed farm structure building to provide a more controllable environment for better crop production, crop protection, crop seeding and transplanting. Moreover, the available space of land for cultivating crops has been significantly decreasing, since more space of land is heavily used for housing and industries in this modern era. In most tropical countries, the use of greenhouse has been growing for commercially horticulture (i.e. fruits, fresh flowers and vegetables) production (Kudang et al., 2006).

Agricultural production is to be increased to assure food security for the growing population. This can be achieved by developing and adopting technologies which can maximize agricultural production. For a plant of given genetic makeup the factors that affect the plant growth are light, temperature, air composition and nature of the growing medium. Hence the crop growing environment is to be suitably modified to maximize production leading to optimum productivity. The environmental factors to be modified include light, temperature, relative humidity, carbon dioxide concentration and nature of growing medium. In the case of open field cultivation only the growing medium can be controlled and the environmental factors which affect crop growth cannot be controlled manually, whereas in greenhouses all the environmental parameters can be suitably controlled or modified. We can cultivate any cop, anywhere during any season inside a greenhouse by modifying crop growing environment. Automatic regulation of crop growing environment is of great importance and most of the cultivators are unable to manage it manually. Greenhouses are framed or inflated structures covered with transparent or translucent material, in which crops can be grown under the conditions of at least partially controlled environment and are large enough to allow a person to walk within them to carry out agricultural operations. A greenhouse protects plants from wind, precipitation, excess solar radiation, temperature extremes, pests and diseases.

1.2 PROBLEM STATEMENTS

Greenhouse environments present unique challenges to good control. Temperature changes occur rapidly and vary widely depending on solar radiation levels, outside temperatures and humidity levels, wind speed direction and the amount of plant materials in the greenhouse. Poor light intensity and high humidity often result in poor fruit set and quality. Proper control of plant disease is critical in greenhouse environments, where high temperatures and high humidity are ideal for diseases to develop. Insect and nematode infections, too, can become rampant under the confined greenhouse conditions. More precise control of temperatures and humidity helps reduce plant stress and diseases.

2. LITERATURE REVIEW

2.1 Automatic System

The application of automatic systems can contribute to agriculture for improving quality, reducing losses, increasing productivity, reducing costs and reducing time for return on investment, planning and making decision, as well as, in reducing the impact to the environment, making easier the work and increasing the quality of life of producer, in order to become more competitive (Teruel, 2010).

Automated systems have the principle of control, using software and hardware, programming and logic controllers, as well as various types of sensor devices and actuators that must work together in a robust way to process data in real time. However it is essential detailed planning and monitoring of subject experts to apply a skilled labor for installation and testing. One of the factors that usually influence in decision making when agricultural automated systems are considered is related to the availability of sensors and actuators that meet the needs of the project and maintain the cost benefit ratio in acceptable limits.

2.2 GREENHOUSE MICROCLIMATE

The assemblage of climatologically parameters forming around living plants inside a greenhouse is termed as greenhouse microclimate. Greenhouse climate is the major driving force influencing fruit quality and productivity of greenhouse crops (Henten *et al.*, 2006). The conditions within the greenhouse that promote crop productivity are referred to as greenhouse microclimate. These can be defined as those climate variables to which the vegetation in the greenhouse will be exposed and include temperature, humidity, carbon dioxide, solar radiation and wind. The microclimate of greenhouse is such a nonlinear, multivariable with strong coupling system that it is impossible to carryout ventilation management accurately if only controlled manually.

2.3 CONTROL METHODS USED IN GREENHOUSE

Among the known control methods and widely used in greenhouses are ON-OFF, proportional (P), Proportional-Integral-Derivative (PID) and in recent times, fuzzy logic systems (FLS), or fuzzy control, Intelligent controls, Artificial neural networks (ANNs), predictive model control (MPC) are employed accordingly to the needs, budgets and control parameters. The ON/OFF control is ideal for variables such as temperature which is between two specific ranges close to each other, allowing the heaters ON and OFF, sliding skylights and fans that regulates this variable; and irrigation systems, allowing the ON/OFF solenoid valves and pumps for the use of irrigation and sprinkler. This nonlinear control is characterized by having a signal in the output of the controller u (t) and an error signal e(t). The signal u(t) remains at a maximum or minimum value depending on whether the error signal e(t) is positive or negative. This is expressed as follows (Ogata, 1997).

$$u(t) = \begin{cases} u_{1,} parae(t) > 0 \\ u_{2,} parae(t) < 0 \end{cases} \quad \ldots(1)$$

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Where $u_{1,}$ and $u_{2,}$ are constants.

The P and PID controls are primarily used individually even to perform the same tasks of the given ON-OFF controls, but with better results. In the proportional control P, the output signal of the controller u(t), is proportional to the error signal e(t). This result is expressed in (2)

$$u(t) = k_p e(t) \qquad \dots (2)$$

Where k_p is considered proportional. Again, in the PID control, use of proportional, Integral and derivative controls together in a single controller is done. In the time domain, this can be seen in (3).

$$U(t) = k_p e(t) + \frac{k_p}{T_i}\int_0^t e(t)dt + k_p T_d \frac{d}{dt} e(t) \qquad \dots (3)$$

2.3 MODELLING THE CLIMATE OF THE GREENHOUSE SYSTEM

In a greenhouse, evaporative cooling devices are used to reduce the temperature when the fan cannot reach appropriate levels for optimal plant growth (Draoui et al., 2011). In equipped greenhouses, cooling evaporation is the second part of the unrealized gain. The heat loss rate depends on the fan speed (Draoui et al., 2011).

$$t_{pad=} H_{out} + \eta_{pad}(H_{wb} - H_{out}) \qquad \dots (4)$$

$$T_{pad=}T_{out} - \eta_{pad}(T_{wb} - T_{out}) \qquad \dots (5)$$

$$Q_{pad=}\rho \dot{V}_{fan} C_p \eta_{pad}(T_{out} - T_{wb}) \qquad \dots (6)$$

η_{pad} : Pad efficiency

T_{out} ,T_{wb} : The difference between the outside temperature and wet bulb (k)

ρ : Density (Kg/m^3)

$\dot{V}$: Fan speed (m/s)

2.3.1 Model of Fogging System

The flow of steam and heat are determined through Ohm's Law and is given as:

$$\dot{e} = KA_{net}(VP_{sat}\,(T_{wb}[T_{air}, rh_{air}]) - VP_{air}) \qquad \dots (7)$$

$$q = \lambda\dot{e}. \qquad ..(8)$$

where:

q: Is the heat transfer between the nebulizer and the air of agricultural greenhouse (W/m^2)

K: Global coefficient of heat transmission (W/$m^2.k$)

P_{sat}: Saturation pressure (Pascale)

P_{air}:: Pression de l'air ambient (Pascale)

$\boldsymbol{\lambda}$: Thermal conductivity (W/$m^2.k$)

2.3.2 Wall Temperature Evaluation Model

The wall temperature evaluation model T_p (Bendimerad *et al.*,2014) is determined based on the average temperatures T_{pi} and T_{pe}

$$T_p = \frac{T_{pi}+T_{pe}}{2} \qquad \dots (9)$$

The indoor and outdoor temperatures are:

$$T_{pi=}T_{air,i} - \frac{K(T_{air,i-}T_{air,e})}{h_{pe}} \qquad \dots (10)$$

$$T_{pe} = T_{air,e} + \frac{K(T_{air,i-}T_{air,e})}{h_{pe}} \qquad \dots (11)$$

2.4 REVIEW OF THE RELATED LITERATURES

Nachidi *et al.*, (2006) have proposed system to control of air temperature and humidity concentration in greenhouses is described by means of simultaneous ventilation and heating system by using Takagi-Sugeno (T-S) fuzzy models and the parallel Distributed Compensation conditions in a greenhouse, using this T-S fuzzy model, the stability analysis and control design problems can be reduced to significant conditions expressed as Linear Matrix Inequalities (LMIs).

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But the system was designed to monitor and control only two environmental parameters which are temperature and humidity.

Abdul-Aziz *et al.,* (2009) proposed a system that is capable of detecting the level of temperature monitoring system using wireless sensor and short message service. This system also has mechanism to alert farmers regarding the temperature changes in the greenhouse so that early precaution steps can take and testing several types. But no irrigation system is provided in the developed greenhouse model.

Cortes & Quijano (2010) used a temperature-humidity multi zone model, which has the same characteristics as some biological models used in behavioural ecology. The use of population dynamics approach to properly allocates the resourcing the greenhouse was used in controlling the variables. A stability analysis is performed under some assumptions, and the simulations illustrated the performance of this method under different operational conditions. But the irrigation sub-system was not considered.

Fitz-Rodiguez *et al.,* (2010) developed an interactive, dynamic greenhouse environment simulator to improve the pedagogy and understanding of the complexity of dynamic behavior of greenhouse environments.

Kookotsa, et al., (2010) designed and constructed an automatic control of greenhouse climate using a fuzzy interface system. However, the operation of fuzzy interface system is inflexible which shall be manipulated within the greenhouse.

Chen et al., (2011) developed a simple greenhouse to describe the effect of shading nets on the inside temperature of a greenhouse by assuming steady state thermal conditions. The detailed microclimate data of an experimental greenhouse with internal and external shading nets were collected during various weather conditions. The model was validated using experimental data collected from various conditions.

3. MATERIALS AND METHODS

3.1 Hardware of the System

The System hardware was designed and implemented on the printed circuit board (PCB), which initialized the system, reads the sensors, displays the values on LCD and take action according to the algorithm. The temperature and humidity sensor modules was used for sensing the inside temperature and humidity of the greenhouse. The Sensor modules require +5 volts supply. The temperature transmitting range is -60℃ to 75℃ while the humidity transmitting range is 30 to 90% RH with accuracy of $\pm$5 % RH.

3.3 SOFTWARE OF THE SYSTEM

The Software was developed using assembly language. The modular programming concept was used so that the system can be easily upgraded. The major software modules developed are:

i. Initialization module.
ii. Sensor module.
iii. Keyboard and Display module.

When the variables are load stack and other necessary registers to their default values set by the programmer, initialize the timers and start them. The Sensor modules sense the inside temperature and humidity one by one, converts them to digital and stores them to the corresponding location. The keyboard and display routine allows the user to set the inside temperature and humidity, also displays the settings and the temperature and the humidity values on the LCD.

3.4 MONITORING AND CONTROL UNIT

After safe system booting, a welcome and guidance message on the LDC can be recognized as shown in Figure 1. Three navigation buttons: set, up and down can be selected according to the operation mode: start, increase and decrease the environmental parameters respectively.

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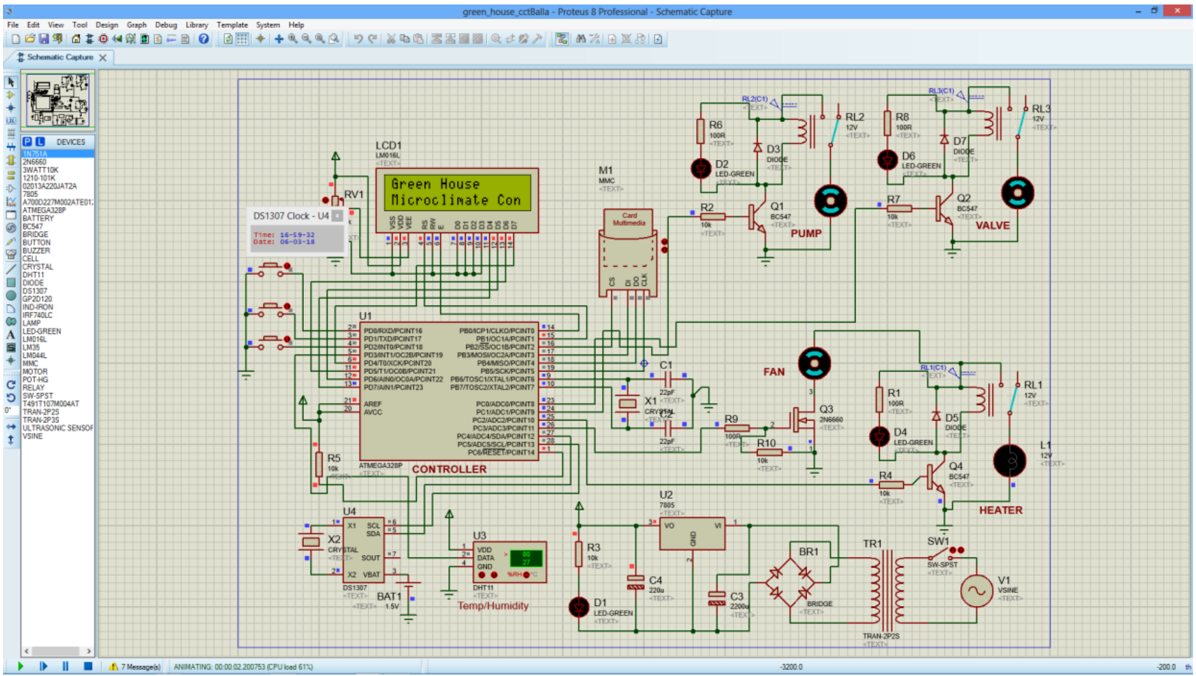

Fig. 1: Circuit design

3.5 SENSING AND RESPONSE UNIT

The sensing and response unit receives the preset sensor values at the monitoring and control unit. Then these values were stored at the FLC memory to maintain the environmental conditions of the greenhouse accordingly. Two environmental conditions can be maintained: temperature and humidity. In the following, the associated response to the change of each parameter can be explored.

3.5.1 Results

An experiment was done to record the Temperature and Humidity readings in greenhouse. The reason for this experiment is to make ensure that the designed system is functioning effectively and the data can be recorded correctly and effectively.

A. Table 1and 2 show the temperature and the humidity readings respectively at different times of the day.

Table 1: Temperature readings

Time	Temperature (^{0}C)
8:00AM	23
9:00AM	25
10:00AM	27
11:00AM	29
12:00PM	33
13:00PM	35
14:00PM	37
15:00PM	35
16:00PM	34
17:00PM	30
18:00PM	28

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Table 2: Humidity readings

Time	Temperature (^{0}C)
8:00AM	60
9:00AM	52
10:00AM	45
11:00AM	33
12:00PM	30
13:00PM	26
14:00PM	26
15:00PM	28
16:00PM	33
17:00PM	35
18:00PM	50

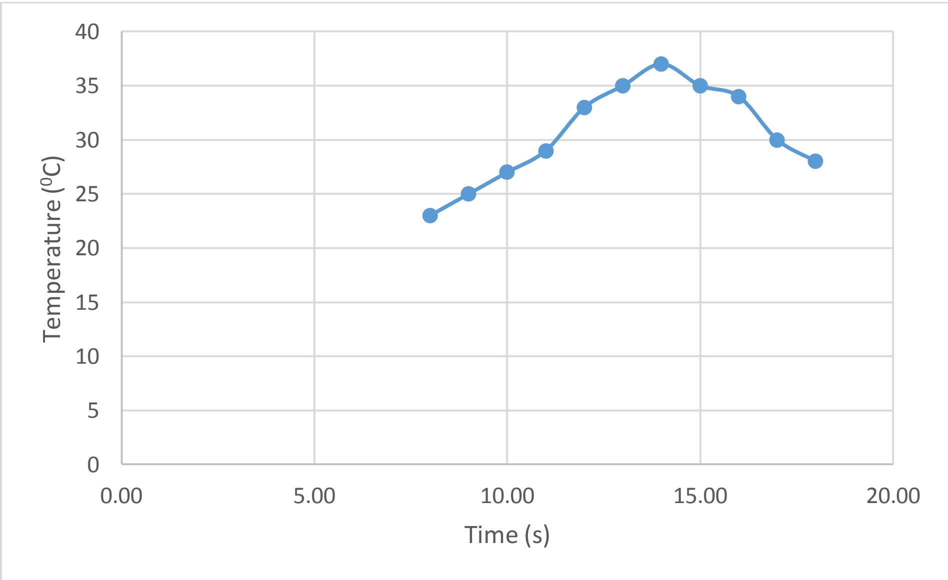

Fig. 2: A graph of temperature (^{0}C) against time (s)

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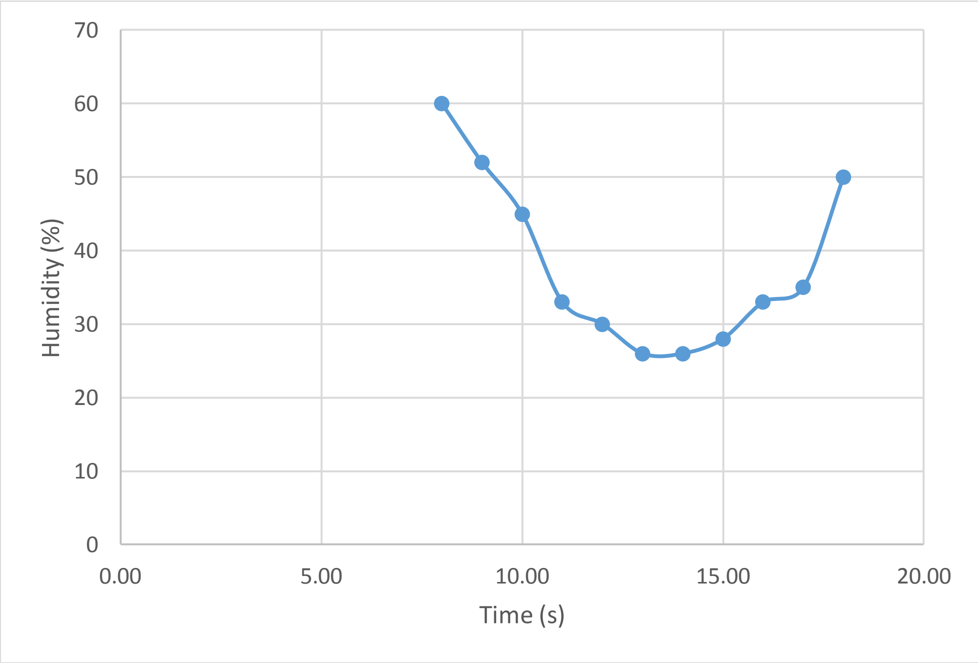

Figure 3: A graph of humidity (%) against time (s)

Figure 4 shows the value of temperature at different time of the day using the temperature sensor LM 35. This shows that the temperature is minimum in the morning and evening but maximum at noon. In figure 3 shows that the humidity is maximum in the morning and evening but minimum at noon. The results show that temperature and humidity has inverse relationship.

B. Hardware implementation

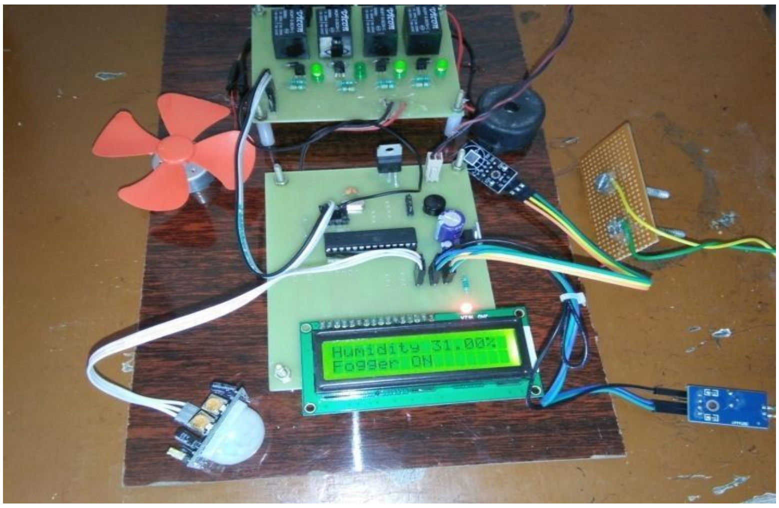

Fig. 4: Hardware implementation

4.0 CONCLUSION

A microclimate monitoring and control system was designed, tested and implemented. The overall tests indicated that the system worked satisfactory. The system has the ability for real-time monitoring the temperature and humidity surround plants and controlling the soil water contents to obtain maximum crop growth in the greenhouse. This research has successfully showed that the implemented system has the ability for monitoring and control of the essential climate parameters under greenhouse.

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