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Design and Simulation of an Automated System for Greenhouse using LabVIEW

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Abstract: Environmental conditions have a significant effect on plant growth. All plants require certain conditions for their proper growth. Therefore, it is necessary to bring the environmental conditions under control in order to have those conditions as close to the ideal as possible. To create an optimal environment, the main climatic and environmental parameters such as temperature, humidity, ground water and the like need to be controlled. These parameters are nonlinear and extremely interrelated, rendering the problem of management of a greenhouse rather intractable to analyze and control through the classical control methods. An automated management of a greenhouse brings about the precise control needed to provide the most proper conditions of plant growth. In this paper, a greenhouse monitoring and control system based on the Supervisory Control and Data Acquisition (SCADA) tool like the LabVIEW is described. In order to fully automate the greenhouse climate control, a comprehensive supervisory system is designed and simulated to serve as a user-friendly interface with the operator.

Key words: Greenhouse . LabVIEW . Front Panel . Block Diagram

INTRODUCTION

In the last decades, there has been a popularity rise of computers for the control of greenhouses. The main improvements in the computer-based climate control are found in data logging, the determination of climate set-points, monitoring and alarm functions [1]. Automated greenhouses based on microcontroller logic or relay switches have minimal upgradeability, while SCADA systems speed up data acquisition, prepare a supervisory level of control over the greenhouse so as to have more flexibility in design and implementation rather than mere microcontroller-based systems.

A greenhouse is seen as a multivariable process presents a nonlinear nature and is influenced by biological processes [2]. The five most important parameters to consider when creating an ideal greenhouse are temperature, relative humidity, ground water, light intensity and CO_2 concentration. In order to design a successful control system, it is very important to realize that the five parameters mentioned above are nonlinear and extremely interdependent [3-5]. The computer control system for the greenhouse includes the following components [6]:

1. Acquisition of data through sensors
2. Processing of data, comparing it with desired states and finally deciding what must be done to change the state of the system
3. Actuation component carrying the necessary actions.

This paper describes a solution to the second part of the system. The information is obtained from multi-sensor stations and is transmitted through serial port to the computer. It will then be processed and the orders will be sent to the actuation network.

SYSTEM INTRODUCTION

The original system includes two main subsystems, namely, the Temperature-and-Humidity control subsystem and the Irrigation-and-Fertilization subsystem. Other subsystems include Lighting and CO_2 subsystems. The System Program contains the running algorithm, which governs the whole subsystems. The real time Data transmit from microcontroller to LabVIEW through serial port of the computer and the required control commands are transferred from the system to the microcontroller. The designed system has nine inputs and eleven outputs. The nine inputs are as follows.

1. Real time nitrate
2. Real time phosphate
3. Real time sulfate
4. Real time calcium
5. Real time soil moisture

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Bit 10	9	8	7	6	5	4	3	2	1	0
Lighting control	CO_2 control	Heating control	Humidifier control	Dehumidifier control	Cooling control	Main water control	Calcium Control	Phosphate control	Sulfate control	Nitrate control

Fig. 1: The 11-bit output of the system

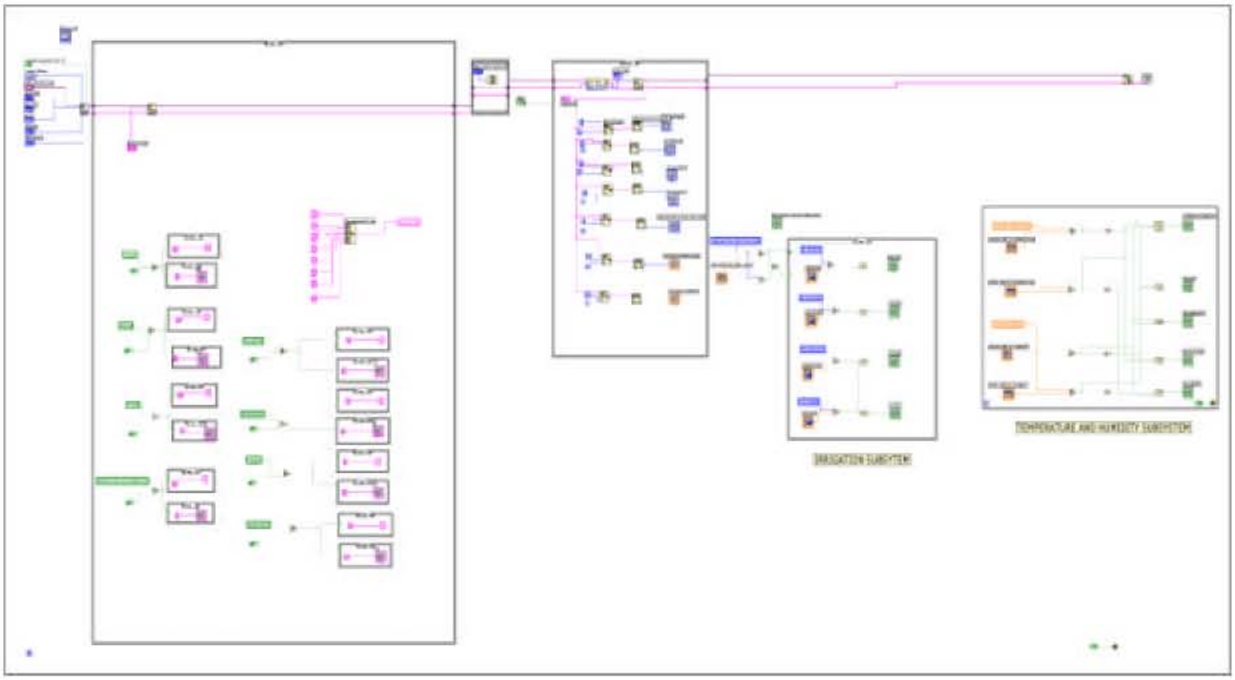

Fig. 2: Block diagram of the main system

6. Real time CO_2
7. Real time lighting
8. Real time temperature
9. Real time humidity

Proportional to the range of their fluctuations, the first seven inputs and last two inputs have been given two and three bytes, respectively. The method is an on-off control and the system output is an 11-bit data and transmitted through serial port to the microcontroller. The eleven outputs are as follows.

1. Nitrate control valve
2. Sulfate control valve
3. Phosphate control valve
4. Calcium control valve
5. Main water control valve
6. Fan and cooling control
7. Dehumidifier control
8. Humidifier control
9. Heating control
10. CO_2 control
11. Lighting control

The system can be set up for any type of plant and vegetation by simply setting certain parameters on the front panel of LabVIEW. The 11-bit output is depicted in Fig. 1.

The entire system is simulated in LabVIEW by National Instruments. The main block-diagram of an automated greenhouse is shown in Fig. 2.

IRRIGATION AND FERTILIZATION SYSTEM

System introduction: Irrigation systems vary in design and layout. Automation is a major consideration. Thus, a greenhouse design should be chosen such that it allows for installations of automated control and autonomously operated equipment [7]. There are many different types of irrigation systems such as automatic drip irrigation and flood floor used in automated greenhouses. By means of this subsystem, the soil moisture level is exactly controlled and human error in estimating and adjusting available soil moisture levels is removed.

Fertilizers like nitrates, sulfates, phosphates and calcium need to be applied through the irrigation system. The fertilizer injection system must be compatible with the installed irrigation system [7].

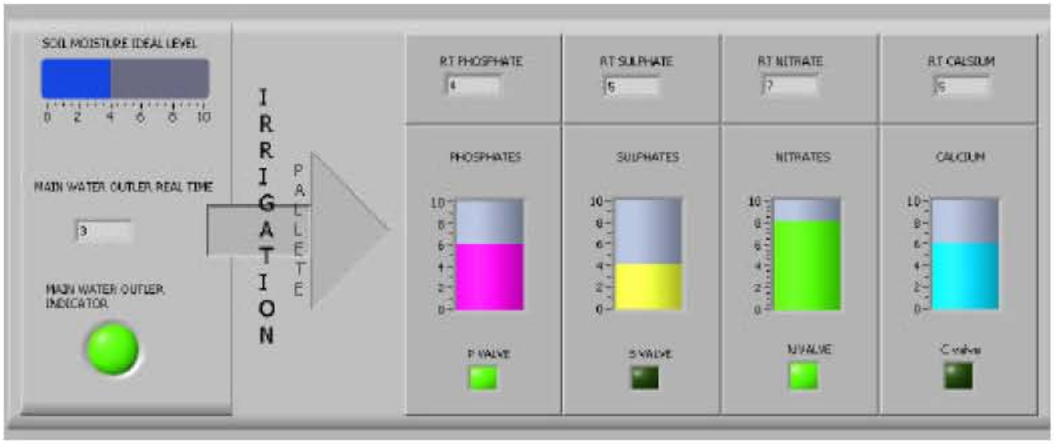

Fig. 3: Front panel of irrigation and fertilization subsystem

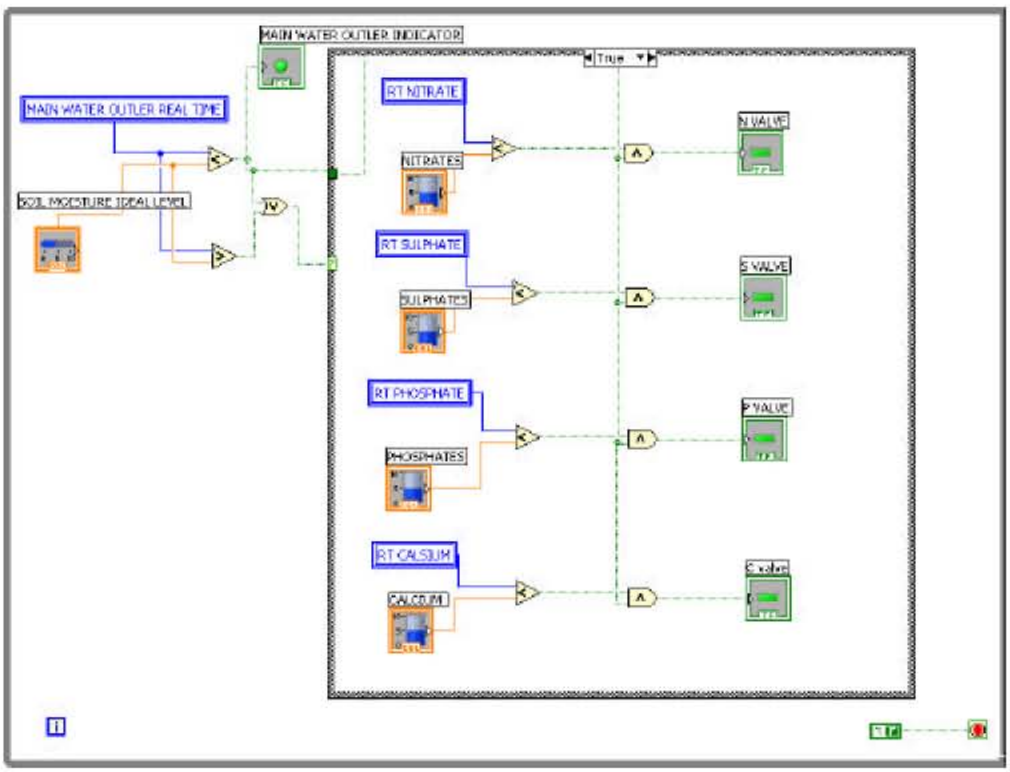

Fig. 4: Block diagram of irrigation and fertilization subsystem

System design and simulation: The irrigation-and-fertilization system consists of a soil moisture control module. This system also performs the proper management of the necessary fertilizers for better plant growth. The phosphate, nitrate, sulfate and calcium tank have their flow control valve, which are connected to the main irrigation tank. For the desired plant, the optimum value of soil moisture, phosphate, nitrate, sulfate and calcium are set through the front panel. The values of soil moisture and fertilizer's contents are measured through sensors in real time which are then displayed in the front panel. Depending on these conditions, the flow control valves are handled. The RT values show the Real-Time values as obtained from the sensors. The corresponding values are labeled as Phosphate RT, Sulfate RT, Nitrate RT and Calcium RT. The valves indicate which pump should be open. The front panel and the block diagram of the designed system are shown in Fig. 3 and 4.

TEMPERATURE AND HUMIDITY SYSTEM

The temperature and humidity system consists of different subsystems as follows. Special attention must be given to these subsystems for the proper functioning of the overall system.

Heating subsystem: Temperature control is necessary for attaining high crop growth, yield and quality. Extreme temperatures may induce stress and associated damage to the plasmatic structures or the photosynthetic apparatus of the plant. Less extreme suboptimal temperatures may delay plant development and affect other plant characteristics such as dry matter distribution [8]. Generally, the protection given by the greenhouse is sufficient to allow the development of crops during winter without the use of heating systems. However, a greenhouse with automated heating facilities presents advantages like increased production speed, possibility of producing products out of season and better control of diseases [6]. Uniform crop growth is very important for most production systems and the heating and ventilation systems have a major impact on producing uniform crops [7].

Ventilation and cooling subsystem: Ventilation systems can be either mechanical or natural (i.e., without the use of fans to move air through the greenhouse) [7]. Whenever the natural ventilation is insufficient, it is necessary to force it, which is done using ventilators. The cooling efficiency can be increased combining the natural and mechanical ventilation systems with air humidifiers. A general type of cooling system uses a porous pad installed in one top side of the greenhouse, which is maintained wet. On the opposite side, an exhaust fan is installed. The air admitted through the pad becomes cooler by evaporation effect [6].

Humidity subsystem: The fog system is formed by suspended pipes on the greenhouse structure, spraying tiny drops of water into the greenhouse, contributing to increase air humidity and decrease the air temperature. Dehumidifier system is used for decreasing the air humidity [6].

System design and simulation: The simulated system in LabVIEW is described in Fig. 5 and 6. The TEMPERATURE PALLETE shows the current temperature and the ideal ranges of temperature for desired crop, while The HUMIDITY PALLETE shows the current humidity and the ideal ranges of humidity. If the temperature falls below a set value, then the heating system is turned on. Similarly, if the humidity rises above a set value, then the dehumidifier is turned on. The method is an on-off control with a certain dead band which can be arbitrarily defined by the user.

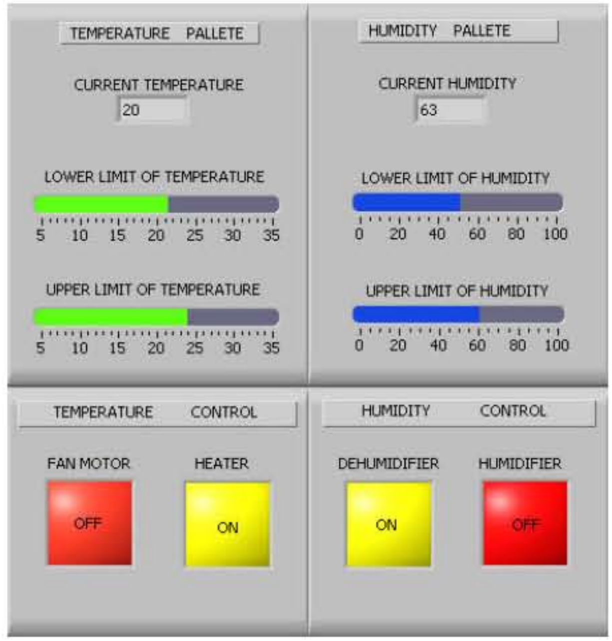

Fig. 5: Front panel of temperature and humidity subsystem

OTHER SUBSYSTEMS

There are other subsystems of importance as the Lighting and CO_2 Injection Units as described below.

Lighting subsystem: Using the Supplemental lighting system is a common way for greenhouse lighting. However it can be done either with Photoperiod lighting system or through Walkway and security lighting. Greenhouse lighting systems allow us to extend the growing season by providing plants with an indoor equivalent to sunlight [9].

CO_2 injection units: The fifth major factor, namely the CO_2 concentration, plays a very important role in the photosynthesis process. The average CO_2 concentration in the atmosphere is approximately 313 ppm, which is enough for effective photosynthesis. A problem arises when a greenhouse is kept closed in autumn or/and winter in order to retain the heat, when not enough air is circulated to have the appropriate CO_2 concentration [5, 10]. In order to improve the growing of herbs inside the greenhouse, it is necessary to increase CO_2 concentration in company with favorable conditions of temperature and light.

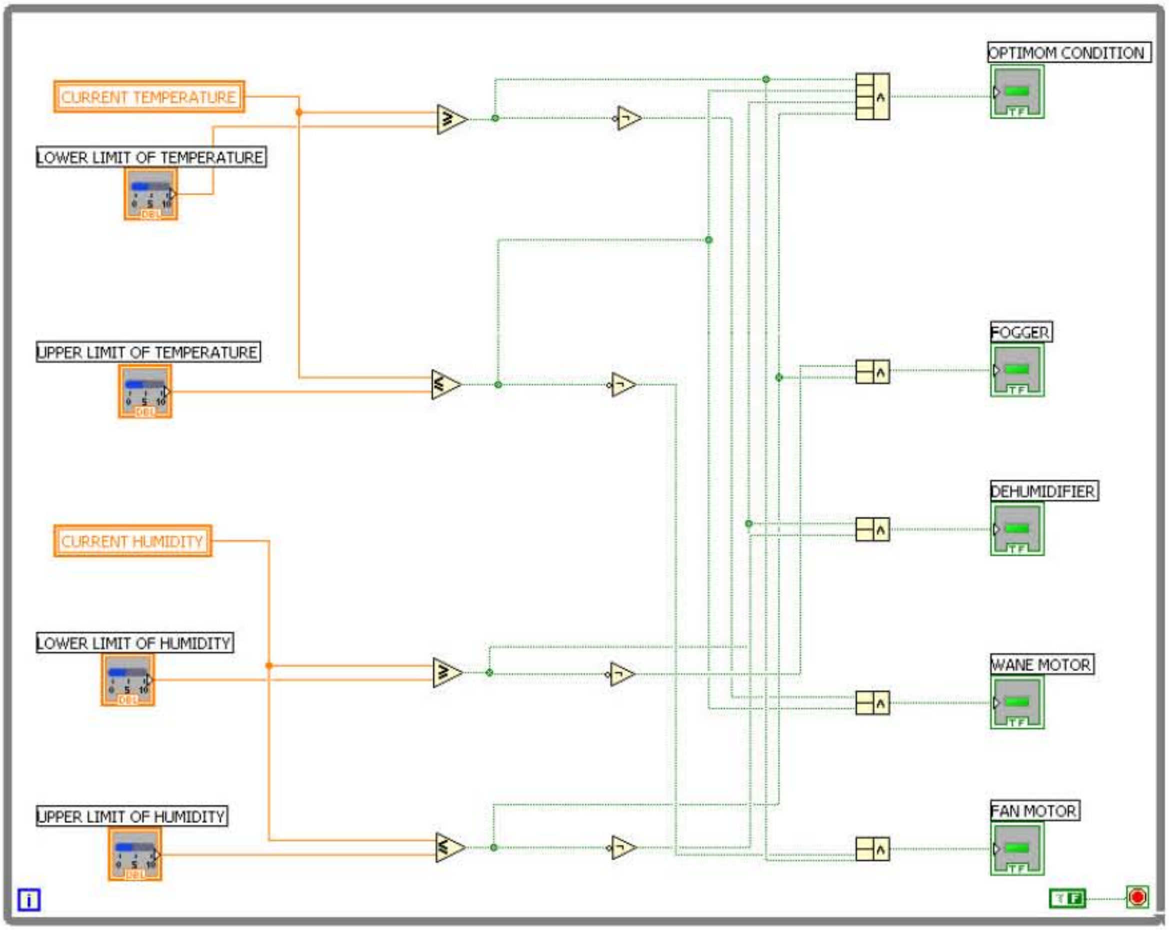

Fig. 6: Block diagram of temperature and humidity subsystem

CONCLUSION

This paper described the design and simulation of a fully automated greenhouse using LabVIEW. For better simulation results, the entire five major interrelated environment variables in a greenhouse-Temperature, Humidity, Ground water, Light and CO_2-were considered altogether. The resulting system was designed in such a way that the system could be easily controlled and monitored by an amateur user who might have no or little technical background on the subject. The main advantages of this simulation are more flexibility, better performance and access to more facilities in the entire system. By means of this simulation, the optimal level of environment and growth factors inside the greenhouse can be achieved. Once the proposed system is designed, standardized, and implemented, it provides an automated and accessible means for a better and convenient control over the greenhouse management in order to increase efficiency.

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