Volume 3, Issue 6, June 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Design of Adaptive Humidity Controller and Practical Implementation for Humidity and Temperature Exclusiveness

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Abstract--The paper presents a low cost, organic, microcontroller driven control system which maintains relative humidity level of a chamber as per the level set by the user along with maintainace of ambient temperature. It can be viewed as an integrated agricultural solution which takes care of the crop yield and post harvested storage by regulating the temperature and humidity factors which are most critical. Unlike other techniques, this approach uses the energy liberated by the stored products in store houses, green-houses to drive humidifiers and dehumidifiers. Along with use of biodegradable materials as the humidity controlling agents, this system presents a robust electronic design for humidity sensor (H20-G) to interact with the microcontroller and an intelligent electronic valve assembly to regulate the flow of air as per the need. A noble algorithm is developed for getting error-free reading from the sensor and comparing it with the user defined value with the help of ADC and microcontroller. In depth analysis in terms of energy requirements and availability is done and the results obtained confirmed that humidity and temperature can be controlled as mutually exclusive functions.

Keywords- Organic; Biodegradable; H20-G; Electronic valve; mutually exclusive

I. INTRODUCTION

This paper presents a noble way to maintain a desired humidity level inside a thermodynamically closed, temperature controlled chamber. In certain fields such as green house cultivation, certain biological and chemical laboratories where it is desired to have a fixed, temperature and humidity level. But, it is nearly impossible to attain this state as it may not be supported by the T-H (temperature-humidity) relationship [1]. Thus the experimental results in researches as well as the agricultural production rate and their quality or the storage life of the agricultural products stored in ware houses suffers inconsistency and degradation. Consequently there is a problem of scientific as well as production and marketing importance. According to the Ministry of Health in 2007 in our country over 65% of child deaths recorded in the range of 0 to 1year occurred in the first 27 days of life [2]. Humidification and dehumidification system available today increment or decrement moisture level, but precise amount of these increment or decrement cannot be controlled by the user to have a fixed humidity level maintained, just as an A.C (air conditioning system) maintains a fixed temperature automatically.

The scope of this work presented here is to maintain a fixed humidity level as per user input within a closed temperature controlled chamber by automated switch mechanism which will drive either humidifier or the dehumidifier into action as per the comparison result between the present humidity level as sensed by a sensor network and the desired value.

It is a self sufficient embedded design which has significant amount of machine learning involved that can direct the flow of air sucked out of the test chamber either through moisture enhancer or dryer unit by an indigenously designed intelligent electronic valve mechanism. The humidifying materials used here are organic, environment friendly, low cost mosses or straw which are easily available. The paper is organised as follows: In the next section we have provided the system design description. In the third section we take an application example where technical details and exact measurement of moisture enhancer, dryer, electronic valve, heat exchangers etc. are calculated for a specific application (as they are application area specific).In the fourth section we have evaluated and demonstrated the results obtained and in the next section, conclusions are drawn.

II. SYSTEM DESIGN

The whole system can be analysed under following sub-parts:

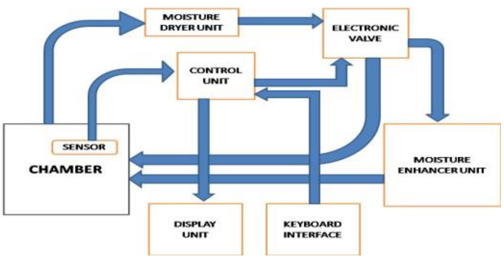

Figure1. Block Diagram

A. Test chamber and the sensor network

The chamber is thermodynamically closed and temperature controlled, so that heat exchanges with external systems can be efficiently controlled. The floor of the chamber has a layer of wet moss or wet straw which will work as a humidifying agent. External walls of the chamber are painted black to use solar energy as an auxiliary heat source. Humidity sensors are fitted in different locations of the chamber as per the dimension of the chamber for humidity measurement. Exhaust fan is installed in the chamber to suck air out of the chamber when humidity level inside the room is to be altered. As temperature and humidity interfere with each other, there is huge wastage of energy [3].Here we are using the heat radiated by the products stored in the chamber and the heat absorbed from the solar radiations to initiate evaporation of water from the underlying wet straw or moss which will increase the humidity level. But as we move towards higher humidity levels the water absorbing capacity of air tends to be saturated. Also in situations where it is desired to decrease the relative humidity levels, air must be sucked out of the chamber and wet or dry air must be reintroduced back as per the need. The sensor used for this specific purpose is H20G humidity sensor which measures the relative humidity through variation in capacitance. It consists of thin parallel plates with dielectric material in between which absorbs and de-absorbs water rapidly changing the capacitance as the relative humidity level change as per the relation C= €A/X where € is epsilon, A is the area of the plates, X is the distance between the two plates, and C is the capacitance.

B. Refrigeration unit

The air sucked out of the chamber by the fan will travel through a thermodynamically sealed pipe to the refrigeration unit which has dehumidifiers stored in it. Air flows through the dehumidifiers, drops its moisture content and thus dry air leaves this unit. The dry air has low relative humidity level and thus higher water absorbing ability. Circulation of coolant through the walls can further increase the efficiency of the unit. In case where de-humidification is needed dry air from this unit is reintroduced back into the test chamber through TS (a thermodynamically sealed) pipe which has dehumidifiers painted on its wall to further decrease the moisture content of air.

C. Electronic Valve

This is an intelligent electronically controlled valve which is capable of directing the air flow either through moisture enhancer unit or through dryer unit. It can be considered as system switch comprised of two electromagnets and a spring-metal arrangement.

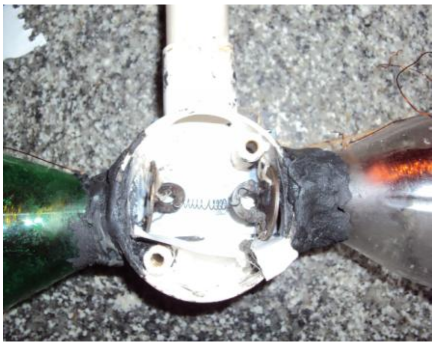

Figure 2. Electronic Valve

The path selection is done by the controlled unit and electromagnet opposite to the selected path is energised which attracts the metal spring arrangement towards it and thus the desired path gets opened for air flow through it. The spring is introduced here to provide restoring force when electromagnets are de-energised so that metal is brought back to its mean position.

D. Moisture enhancer unit

It increases the moisture content of air by repeated striking against the plates which has layers of wet moss or straw upon them

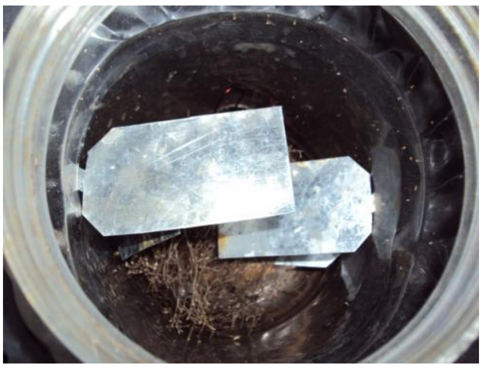

Figure 3. Moisture Enhancer Chamber

Humidified air is re-introduced back into the test chamber using TS (a thermodynamically sealed) pipes and this process goes on till the desired humidity level is attained.

E. Control unit

The control unit is the backbone of the system which comprises of a 8051 microcontroller which has program feeded in its memory to take decisions after comparing the relative humidity level, between the measured value returned by the sensor network and the user defined value taken through an input device. It also energises and de-energises the appropriate electromagnet as per the requirement through relay circuitry. A program is developed in embedded-C platform which implements the algorithm presented and the program is burned into the flash memory of the microcontroller. Here the sensed value is compared with the user defined value passed into the microcontroller using the keyboard interface [4].

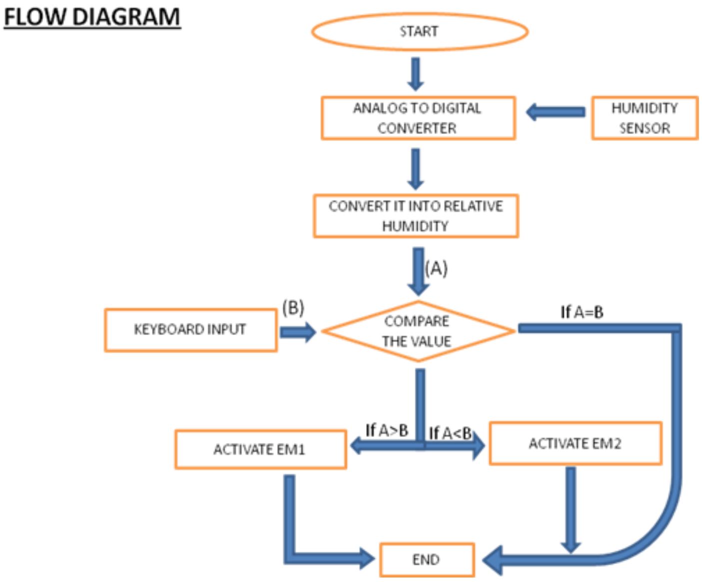

Figure 4. Flow diagram for Microcontroller

The circuit consists of a humidity sensor H20-G whose output is feeded to the 8-bit ADC 0804.The output is then feed to the microcontroller 8051(to make the system cost effective).

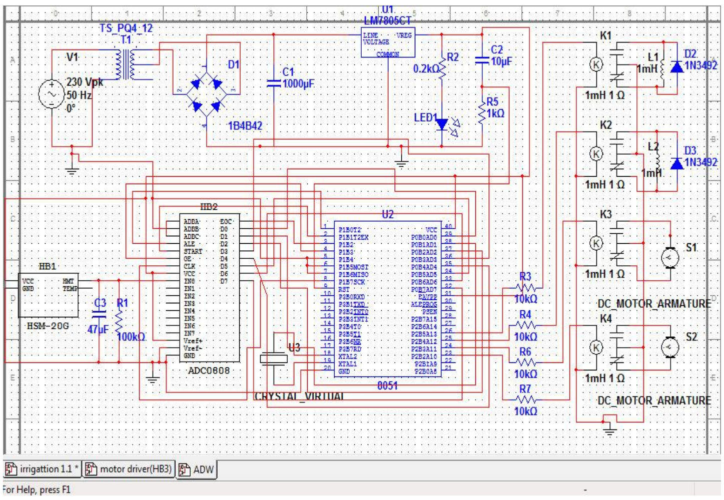

Figure5. Circuit diagram on Multisim 6.0

Here an algorithm is implemented using keil IDE to convert the value into corresponding relative humidity level and then comparison is done. Based on the results, decision is taken as per the rules laid in machine learning section and the required outputs are switched on/off. To reduce the effect of hysteresis in electromagnets, freewheeling diodes are shunted which is a new feature added in electromagnet design.

III. APPLICATION EXAMPLE

In this section we take a example where our system is designed for a specific situation.

A. Energy balance

1) Heat availability:

Here the test chamber is in the form of a cylinder with radii (r)11.5 cm and height (h) is 18.5 cm. thus the volume of the test chamber is calculated by the relation, V=$\pi r^2 h$,

Where,

V = volume of the test chamber.

$$=3841.20 * 10^{-6}\ m^3.$$

Now we are using the heat radiated by items stored in the test chamber. Here we are considering an apple storage ware house which is half filled with apples .Volume of one apple (V_f) can be calculated as

Volume of fruit:-

$$V_f = 4/3 * \pi r^3$$
$$= 4/3 * 3.14 * 3^3$$
$$= 113.04*10^{-6}\ m^3$$

Now, total number of apple stored in the test chamber = 15

By the Stephen's law of radiation, we know that Q = σ e T^4 A

Where,

Q = heat radiated by the surface of apple

σ = Stephen's constant

T = temperature in Kelvin

e = emissivity constant

A = area of apple whose average radius is 3 cm.

$$Q = 5.67 * 10^{-8} *.9 * 298^4 *4 * 3.14 *3^2$$

= 4.54 J /s

As heat is also absorbed along with radiation so the amount of heat available for starting the evaporation process is 1/10 0f the total heat radiated.

Total heat available by fruits

$$= 1/10 * 4.54 * 15$$
$$= 6.75\ J/s$$

Heat available from the black surface of the test chamber can also be calculated by the Stephen's radiation law as

$$Q_1 = \sigma\, e\, T_1^{\,4} A_1$$

Where,

Q_1= heat radiated by the surface of test chamber

σ = Stephen's constant

T_1= temperature in Kelvin

e = emissivity constant

A_1= area of the outer surface of test chamber whose radius is 11.5 cm.

For cylindrical chamber total surface area with one end covered = $2\pi rh + \pi r^2$

$$= 5.67 * 10^{-8} * 298^4 * 3.14 *(2*11.5*18.5*10^{-4})$$

= 59.7 J/s

As heat is also absorbed along with radiation so the amount of heat available for starting the evaporation process is 1/10 0f the total heat radiated

$$= 1/10 * 59.7$$

=5.97 J/s

Total heat available for evaporation = (6.75 + 5.97) J/s

= 12.72 J/s

This heat is used to start the evaporation process from the underlying moss or straw.

The amount of evaporated water can be expressed with the empirical equation as:

$g = \Theta A (x_s - x) / 3600$

where,

g = amount of evaporated water (kg/s)

Θ = (25 + 19 v) = evaporation coefficient (kg/m^2h)

v = velocity of air above the water surface (m/s)

A = water surface area (m^2)

x_s =humidity ratio in saturated air at the same temperature as the water surface (kg/kg) (kg H_2O in kg Dry Air)

x = humidity ratio in the air (kg/kg) (kg H_2O in kg Dry Air)

2) Heat Required: Most of the heat required for the evaporation is taken from the water itself. To maintain the water temperature heat must be supplied.

The heat supplied can be calculated as:

$q = h_{ew}\ g$

Where,

q = heat supplied (kJ/s, kW)

h_{we} = 2600 - evaporation heat of water (kJ/kg) at 25^0 c

For a circular cross section of radius 11.5 cm and *0.5 m/s* velocity of air above the surface, the evaporation can be calculated: g=(25 + 19 (0.5 m/s)) $(3.14 * 11.5^2 * 10^{-4})((0.02\ kg/kg)-(0.0098 kg/kg)) / 3600$ $=4.05 * 10^{-6}$ J/s.

The heat supply required to maintain the temperature can be calculated:

$q = (2600 kJ/kg)\ (4.05 * 10^{-6}) = 10.5$ J/s.

Thus we can see that the total heat required to start the evaporation process is less than the heat available.

B. Automotive cooling fan : The rating of exhaust fan used to suck air out of the chamber is as follows

Rated Voltage (AC)	Current (A)	Speed (RPM)	Air Flow (CFM)
220-240/50HZ	0.10	2000	78.5

C. Adsorption on Silica Gels

The water absorbing capacity of dehumidifier used that is silica gel is approximately 1.2 times its own weight. So we have taken 5 grams of silica gel for dehumidification in the refrigeration unit [5] [6].

D. Moisture enhancer unit

1) The cylindrical unit has a radius of 4 cm and height of 14 cm in which 8 rectangular plates of dimension 4cm * 8cm is attached in alternate fashion.
2) The heat available in this unit for evaporation of water from the wet moss layer, calculated by the Stephen's law mentioned above = 15.72 J/s
3) And the heat required to start the evaporation process = 6.5 J/s.

E. Electromagnet

The electromagnet designed for automatic intelligent electronic valve has the following specification:-

Number of turns (N) = 1000Current (I) = 1 ampere Area of cross section of iron core = $3.14 * 10^{-4}\ m^2$

Length of the iron core (L) = 6cm

Magnetic field generated at a distance of 1 cm along the axis of the electromagnet

$B = \mu_0 / 4\pi\ (2 * M * L) / d = 12$ T. Where, M = N I A

d = distance from the electromagnet

Therefore, Magnetic force experienced at that point (F= BIL) = 0.72 N

Therefore, the elongation of the spring having spring constant 8.5 can be up to 8.4cm. So the metal will tightly block the path of flow of air on one side. It will come back on its initial position due to restoring force just after the removal of signal to the electromagnet [7] [8]. Freewheeling diode will counter the stray magnetism effect and will demagnetise it instantly.

IV. RESULT

After developing the system and practically analysing the various parameters, we can infer that the system designed is capable of maintaining a fixed humidity level with optimum (low) temperature. Thus we are able to achieve our goal to control temperature and humidity as two mutually exclusive functions.

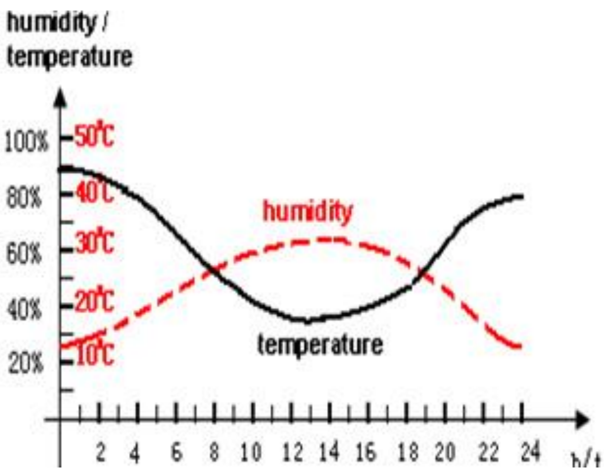

Figure 6. Graph(existing model result)

The relation in between relative humidity and the temperature at various time instants is shown in figure4. This is the typical result of existing models where the parameters are mutually inclusive.

In contrast the results achieved by this system (figure5) after practical implementation and field study results, it can be seen that both can be individually controlled. In this figure humidity level is being increased from 40% to 70% in about 10 seconds which proves it to be an efficient system.

To analyse the practical utility of the system we conducted a field study in which apples were stored and compared with those stored in typical warehouse condition. Results show that stored products in this system has longer storage life.

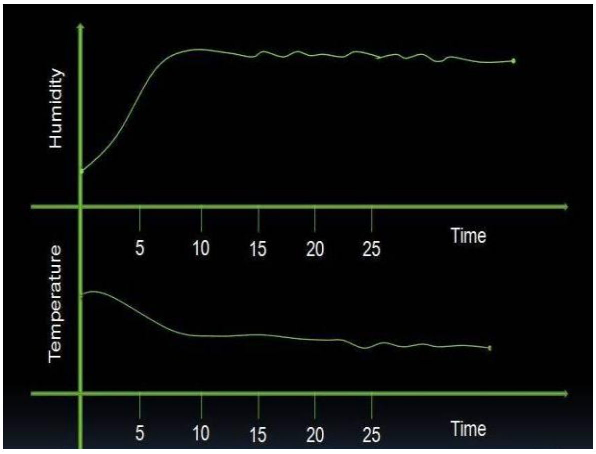

Figure7. Humidity and temperature w.r.t. time (system presented)

V. CONCLUSION

This paper presented a noble, cost effective, bio-friendly design to control relative humidity level as per the user need and its implementation. The energy used in this electronic device is mainly derived from the natural heat radiations reflected by every object at all temperature, and with minimal use of electricity. The design of electronically controlled, smart valve and its precise control using specially designed algorithm to control the flow of air plays a very crucial part. This device will not only improve the net agricultural productivity but also will be fruitful to improve the level of preciseness in results obtained in various humidity sensitive experiments. It can be further used to control the amount of the soil PH level or for spraying chemicals in the fields where precision is needed just by altering the sensor used.

REFERENCES

[1] Qiu Yuqun, Qiu Zhaoguang, “Research and development and the experiment confirmation of high accuracy constant temperature and humidity air conditioning”, Refrigeration and Air-Conditioning, vol. 6, March 2006, pp. 82–83.

[2] Gordon B. Bonan. Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests. 13 June 2008 Vol. 320 Science

[3] Zheng Zhongjun, “Temperature and humidity computer control System”, Journal of Computer Applications, vol. 22, Jan. 2002, pp. 76–77.

[4] Wang Jin-Yong, Jia Qing and Xie Jian. The Realization of Dual-net Control System with control logic [J]. Measurement & Control technology, 2001,(2):24226.

[5] Spence Konde, "Preparation of High-Silica Zeolite Beads from Silica Gel," retrieved 2011-09-26

[6] Fisher Scientific (1997-02-09). ""Silica Gel Dessiccant"[sic]". Retrieved 2008-01-12.

[7] Fleming, John Ambrose (1902). Magnets and Electric Currents, 2nd Edition. London: E.& F. N. Spon. pp. 173–174

[8] Sherman, Roger (2007). "Joseph Henry's contributions to the electromagnet and the electric motor". The Joseph enry Papers. The Smithsonian Institution. Retrieved 2008-08-27

