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Design of Air Conditioning Automation for Patisserie Shopwindow

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***Abstract*—**Having done in this study, air-conditioning automation for patisserie shopwindow was designed. In the cooling sector it is quite important to cooling up the air temperature in the shopwindow within short time interval. Otherwise the patisseries inside of the shopwindow will be spoilt in a few days. Additionally the humidity is other important parameter for the patisseries kept in shopwindow. It must be raised up to desired level in a quite short time. Traditional patisserie shopwindows only allow controlling temperature manually. There is no humidity control and humidity is supplied by fans that are directed to the water at the bottom of the shopwindows. In this study, humidity and temperature sensors (SHT11), PIC, AC motor controller, DC motor controller, ultrasonic nebulizer and other electronic circuit members were used to simulate air conditioning automation for patisserie shopwindow in proteus software package. The simulation results showed that temperature and humidity values are adjusted in desired time duration by open-loop control technique. Outer and inner temperature and humidity values were used for control mechanism.

***Keywords*—**Air conditioning automation, temperature and humidity, SHT11, AC motor controller, open-loop control.

I. Introduction

IDEAL temperature and humidity values for chocolate kept in the patisserie shopwindow are +18°C and %55 RH (relative humidity). Ideal temperature and humidity values for birthday cake kept in the patisserie shopwindow are +4°C and %70 RH (relative humidity). Traditional patisserie shopwindows only allow controlling temperature manually. There is no humidity control and humidity is supplied by fans that are directed to the water at the bottom of the shopwindows. Additionally desired humidity values are never be reached due to techniques used for supplying humidity. Opening and closing the shutter of the shopwindow causes temperature change in the shopwindow and reaching the desired temperature takes long time due to manuel control of the cooling system. Last but not least the temperature and humidity difference between the shelves of the shopwindow causes difference spoilt time for the food kept in different shelves. This study aims to design an automation system for patisserie shopwindow that will provide required temperature and humidity values in a short time. This system will also remove the temperature and humidity value differences between difference shelves. To do this;

1) Required humidity value will be obtained by using piezoelectric based ultrasonic moisturizing equipment.
2) Required temperature value will be obtained by microcontroller based control system.
3) The temperature and humidity value difference between the different shelves will be removed by using additional fans.

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II. Related Works

At part load, humidity of the air-conditioned space tends to rise, as zone temperature is controlled through reducing the air-conditioner's cooling capacity [1]. When the dry bulb temperature of the indoor air set point is satisfied, the compressor will stop running. However, the indoor humidity may be out of the comfort region. Lin and Deng [2] studied the design cooling capacity of room air-conditioners in subtropical zone, and the result suggested design the cooling capacity according to 70–80% the cooling load. The reason was that when the zone temperature reaches the set temperature, compressors would stop working, thus, decreasing cooling capacity of room airconditioners would help increase the compressor running time, thereby enhancing the dehumidification capacity. During the compressor off time, the supply fan does not stop, thus condensed water on the evaporator surface will evaporate continuously and resulting in water vapour blown back to the indoor air. During the compressor on/off cycling, customers will experience "dry" and "wet" condition from time to time. If customers need to control the humidity constant, in addition to refrigeration systems, they need to also buy a dehumidifier or set the indoor air temperature lower than demand temperature, such as 22–24◦C. The former option would increase the cost of equipment, while the latter one consumes more energy and make people feel cold.

In summary, due to the coupling process of heat and moisture of current residential air-conditioners, and return air temperature as the control parameter, when the load of heat and moisture does not match, it will cause indoor high humidity. Therefore, the temperature and humidity separate control air-conditioners is very necessary in hot and humid areas. Mechanical cooling and reheating has been widely used in many applications to control indoor humidity. However, this method has been known to be energy intensive [3]. Adsorption or absorption systems are efficient for air dehumidification. A liquid desiccant based independent humidity control (IHC) air-conditioning system driven by heat pumps was studied by Zhu et al. [4]. The system consists of a liquid desiccant fresh air processor and a high-temperature chilled water system. The average EER of the fresh air processor and the high-temperature refrigerator are 6.24 and 4.38, respectively, and the average EER of the whole IHC system is 5.28. Niuetal [5] proposed a HVAC system combining chilled ceiling with desiccant wheel, in which temperature and humidity are decoupled. The results indicate that it can save up to 44% energy in HongKong. Laetal. [6] combine the rotary desiccant dehumidification and regenerative evaporative cooling. In addition to dehumidification, the system is capable of producing chilled water, thereby realizing separate temperature and humidity control without increasing electrical load. It is found that the system can achieve a thermal COP higher than 1.0 and an electric COP about 8.0. The temperature of chilled water produced by the systemisaround14–20◦C.This chilled water can be used with capillary tube mats for radiant cooling. However, they are bulky and they require outside heat sources for regeneration, which is not so often to obtain on site, especially in residential houses. Besides, control methods of traditional air-conditioning system have been investigated to control indoor humidity to get better indoor environment. Sekhar and Tan [7] find that the indoor high humidity in hot and humid climates can be attributed to the inadequate dehumidifying performance of the cooling coil. Poor dehumidifying coil performance results from the selection and installation of an oversized coil and the conventional strategy of modulating the chilled water flow rate as the only available control method. The findings Show that the dehumidifying performance of the oversized coil at reduced loads during normal operation can be significantly enhanced by changing the effective surface area of the coil through a simple manipulation of the effective number of rows of coil operation. Huh and Brandemuehl [8] focus on a temperature and humidity control technique of DX air-conditioning system, emphasizing the humidity control issue in meeting both sensible and latent building loads. While there is a rich literature on all of the various aspects of the temperature–humidity separate control, there has been no effort to address small size and compact air-conditioner to satisfy both temperature and humidity constraints in residential houses, which can be easily installed and maintained. The present sensible heat handling units include dry fan coil and radiation panel. Radiation panel is a new kind of air conditioning device removing heat through radiation and convection. The water supply temperature cannot be lower than the indoor air dew point temperature in case of condensation on its surface. Thus, the temperature of the cold water supplied to the radiation panel is generally controlled 1 or 2 ˚C higher than the indoor air dew point, and in most cases 16–18˚C is fine. However, the present standard water supply temperature of an air-conditioning unit is always around 7 C, which is much lower than the indoor air dew point temperature. Consequently, heat exchangers or mixture valves are needed to get appropriate cold water temperature [9], [10], which is obviously a waste of energy according to the second law of thermodynamics.

III. Material and Method

The automation system first designed and simulated in Proteus software package. Later on the system is implemented in laboratory environment. The details are as follows. The patisserie shopwindow has dimension of 45cmx1.5m x1 m. It has a cooling system inside that consists of a fan, compressor and condenser. It is controlled as manually with a button and LED display. By the aid of an LED display desired temperature is entered and thermostat helps to stop cooling system at the desired temperature degree. For moisturizing aim three fans are used and directed to the water at the bottom of the shopwindows. They are only controlled with a button when the user decided that the humidity is not enough for the shopwindows. Required humidity level can never be reached due to using these three fans directed to the water. Last but not least there exists temperature and humidity differences between two different sections of the shopwindows (bottom, and up section separated by two shelves). So that to reach the desired level of the temperature and humidity level and also to have heterogeneous temperature and humidity values in each section of the shopwindow three important factors are considered:

1) *Fan of the cooling system must be adjusted toadjust the cooling time (5 different voltage levels for control)*
2) *To use piezoelectric based ultrasonic moisturizing equipment to reach desired level of humidity (10 different frequency levels for control)*
3) *To use 3 fans for removing temperature difference between two sections (5 different voltage levels for control)*
4) *To use1 fan directed to piezoelectric based ultrasonic moisturizing equipment for removing humidity difference between two sections (5 different voltage levels for control)*

To implement upper mentioned items, SHT11 temperature & humidity sensor (8), one AC motor controller (one phase 1500 Hz), 4 DC motor controller, one PIC16F42 and one computer are used. 8 different SHT11 are located at the bottom, middle and up sections of the shopwindows. They are all connected to PIC16F42. Printed Circuit Board (PCB)and the circuit itself are presented in Fig. 1 and Fig. 2, respectively.

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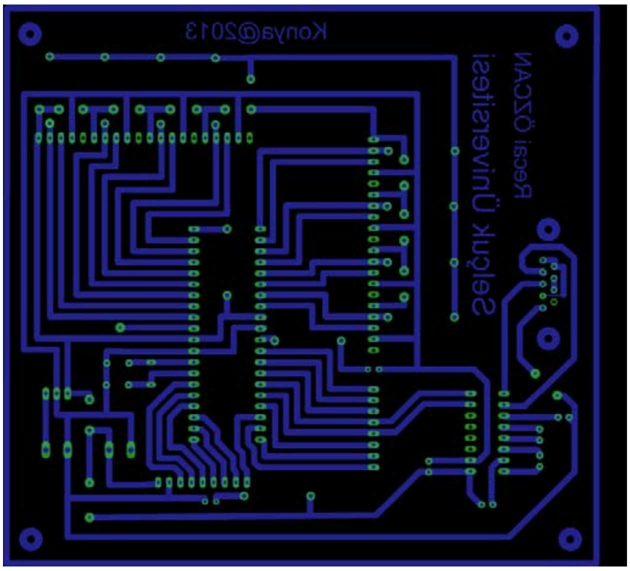

Fig. 1 PCB of designed system

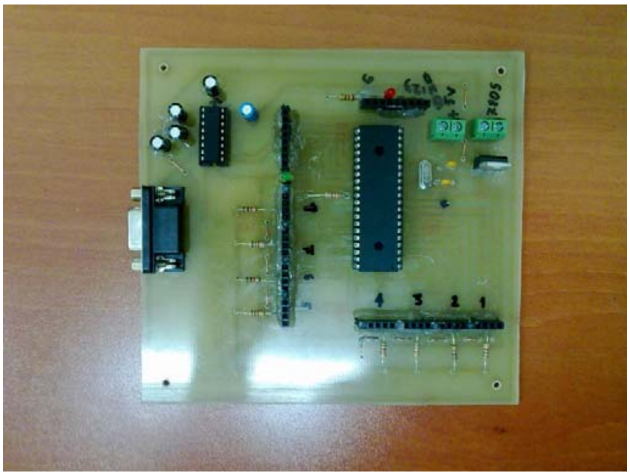

Fig. 2 The circuit of designed system

Followings are the controlled variable (Input & Output) and conditions in the system:

INPUT

1) Temperature
2) Humidity
3) Shelf lower-upper temperature difference
4) Shelf lower-upper humidity difference

OUTPUT

1) Cooling fan
2) Mixer fan
3) Moisturizing

INPUT

1)Temperature (Degree)

If Temperature<4 then cooling fan level is 0
If Temperature=4 then cooling fan level is 1
If Temperature=6 then cooling fan level is 2
If Temperature=8 then cooling fan level is 3
If Temperature=10 then cooling fan level is 4
If Temperature>10 then cooling fan level is 5

2)Humidity(%)

If Humidity<10 then humidity level is 10
If Humidity>10 and humidity<20 then humidity level is 9
If Humidity>20 and humidity<30 then humidity level is 8
If Humidity>30 and humidity<40 then humidity level is 7
If Humidity>40 and humidity<50 then humidity level is 6
If Humidity>50 and humidity<60 then humidity level is 5
If Humidity>60 and humidity<70 then humidity level is 4
If Humidity>70 and humidity<80 then humidity level is 3
If Humidity>80 and humidity<90 then humidity level is 2
If Humidity>90 and humidity<100 then humidity level is 1

3) Shelf lower-upper temperature difference

If temperature difference is=0 then fan level is 0
If temperature difference is=1 then fan level is 1
If temperature difference is=2 then fan level is 2
If temperature difference is=3 then fan level is 3
If temperature difference is=4 then fan level is 4
If temperature difference is>4 then fan level is 5

4) Shelf lower-upper humidity difference

If humidity difference is=0 then mixture fan level is 0
If humidity difference is=10 then mixture fan level is 1
If humidity difference is=20 then mixture fan level is 2
If humidity difference is=30 then mixture fan level is 3
If humidity difference is=40 then mixture fan level is 4
If humidity difference is>40 then mixture fan level is 5

The interface prepared for the system is shown in Fig.3. As can be seen from the Fig. 3 “Sensör” means “Sensor”, “Sıcaklık” means “Temperature”, “Nem” means “Humidity”, “Port Aç” means “Open Port”, “Port Kapat” means “Close Port”, “Kayıt” means “Record”, “Kayıtİptal” means “Record Cancel”, “OrtalamaSıcaklık” means “Average Temperature”, “OrtalamaNem” means “Average Humidity”, AC Fan, DC Fan and “NemKad” means “Humidity Level” exist. Seeing current temperature and humidity values of each sensor (From 1 to 8), selection of the port for communication between PC and prepared circuit, recording temperature and humidity values of each sensor as long as the user wish and average values of temperature and humidity, seeing current AC & DC fan level and also current levels of AC Fan, DC Fan and piezoelectric based ultrasonic moisturizing equipment are possible from this interface. The program is written in C# programming language. PIC communicate with the sensors at every 100millisecond. Last but not least interface allows somebody to see the records under “Kayıt” section and also to send the record to other tools by using “Gönder”-Send label.

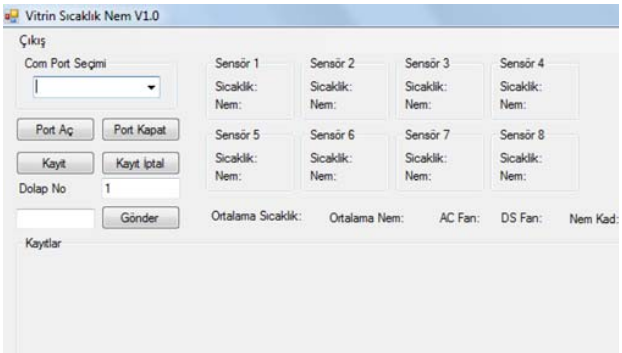

Fig. 3 Interface of the designed system

IV. Conclusion

The designed system reaches required temperature and humidity values within short time. The system can be improved by adding fuzzy control additional to PID system. The more sensitive and efficient results can be obtained in a shorter time duration.

Acknowledgment

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