Fuzzy Control Of An Air Conditioning System For A Hospital In Hot And Humid Climates

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Abstract — This paper presents a simulation process for an air conditioning system for a hospital in hot and humid climates using the fuzzy logic control.
The study deals with a two-stage experimental test rig, specially designed, to simulate the air conditioning system for a hospital in damp-warm areas. The dry bulb temperature (DBT) and relative humidity of the supply air to the system rang from 35 to 40oC and 90 to 95%, consequently, the air supply to the conditioned space should fulfill the required air quality for the hospital.
The experimental results and the fuzzy logic control output are in a good match, which is the first step of using the fuzzy logic control in the HVAC system.

Key words:
Air conditioning – hospitals – fuzzy logic control.

INTRODUCTION

HVAC System in hospitals and other health care facilities must do more than simply provide for a comfortable working environment. Their design also must provide ventilation that minimizes exposure hazards for patients, workers and visitors [1].
"Well-designed HVAC systems enhance the other facets of the built environment to offer a 'healing environment. Building-related illnesses, especially those associated with airborne infectious agents, continue to be a challenge for health care organizations that treat infectious patients and those that are susceptible to environmental microbes, such as Legionella.." said Anand Seth, P.E..
Headaches, irritated eyes, coughing, sneezing, drowsiness, fatigue, nose and throat irritations, nausea and dizziness are the common symptoms often caused by poor indoor air quality.
The American College of allergists states that 50% of all illnesses are either caused by, or aggravated by, polluted air.

HVAC SYSTEM REQUIREMENTS FOR HEALING ENVIRONMENT

The basic differences between air conditioning for a hospital and for any other building, are that in hospitals a wide variety of environmental conditions are required in various departments [2].

Table I presents the outdoor air requirements for ventilation [3].

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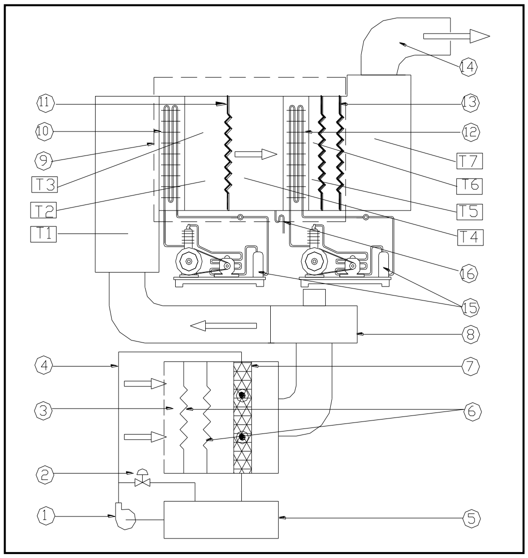
Hospitals, Nursing and Convalescent homes.	Max. Person /100 m^2	Outdoor air required L/s-Person	Comments
Patient rooms	10	13	Procedures generating contaminants may require higher rates
Medical procedure	20	8	
Operating theaters	20	15	
Recovery or ICU	20	8	
Physical therapy	20	10	
Autopsy rooms		2.5 L/s-m^2	Air shall not be re-circulated into other spaces

The control of temperature and relative humidity has now become one of the indoor air quality issues of the day. The temperature control should be on an individual room basis. For example, the operating theater requires a temperature of about 18 to 22^{o}C, with relative humidity held to a range between 50 and 60%. Nursing rooms require 24 to 26^{o}C and 55% relative humidity [4].

HEPA [High Efficiency Particulate Air] filters are effective in achieving a low bacteria count by removing virtually all particles from the air stream down to one-micron (1μm) in size [95%] [5].

To achieve the clean conditions needed, the supply air must be filtered through high efficiency particulate air filters ULPA [Ultra Low Penetratic Air] filters 99.999% min dust spot efficiency for particles of 0.12 μm diameter. Activated carbon, organic zeolite, electrostatic and UV light may be also used to purify air.
Hospital isolation rooms provide safety and protection for patients, staff and visitors. Infection and disease can be contained by maintaining a pressure differential between the isolation room and surrounding areas. Rooms held at negative pressure are used for patients with highly infectious diseases such as tuberculosis (TB). The negative pressure contains the contamination within the room so it can be filtered and exhausted. Similarly, patients who are vulnerable to disease and infection, such

as bum victims, are put into isolation rooms held at positive pressure to keep contamination out.



1 water pump	7 humidifier	12 re-heater
2 by-pass valve	8 air fan	13 supply air
3 air inlet	9 AHU	14 condensing units
4 control box	10 first cooling coil	15 condensate pipe
5 water tank	11pre-heater	T1-T7 climatic measuring points

Fig. 1 Experimental Test Rig (general layouts)

DEFINITION OF THE PROBLEM

In damp-warm and dry-hot tropical areas, high temperature become a serious matter, especially if the air humidity is also high, therefore, hospitals in tropical areas are in most instances, equipped with air conditioning plants which predominantly serve the purpose of air dehumidification and secondly of temperature reduction.

Too much humidity promotes the growth of molds and mildews. Low humidity level promotes bacteria, viruses, and other organic and non-organic thins that can be hazardous to our health. As shown in figure 2-4, is a chart that will help us see that keeping the proper humidity levels in air-conditioned space will also keep out things that can affect our health.

Such system can be accomplished by using single stage (one cooling coil followed by one heater) or by two stage units, which improves the processes of heat transfer in cooling coils This is due to the fact that the total condensate will be distributed on two coils instead of one.

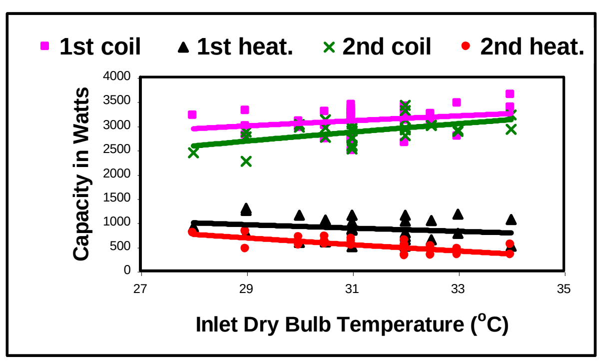
Controls are required where a steady state condition (such as room temperature & humidity) must maintained, and the load on the system fluctuates.
The use of digital computer has facilitated many of the advances made in the HVAC industry. Computers have allowed the design of more complex but more reliable components: [3]
Programs have reduced the time required for determining building requirements and have permitted better a faster design of duct and piping systems.

The function of the controls is to match the output of the equipment to the demands of the load. When the load does not vary, no control required.
Healing environment has many special design issues including pressure, ventilation, climate-control and air filtration. A ventilation system must be designed to maintain proper area pressure, contamination removal and thermal comfort.
The main objective of this study is to investigate the effectiveness of the fuzzy logic control on heating, ventilation, and air conditioning system (HVAC) for hospitals located in warm-damp areas, where control is a major controversial issue.

THE EXPERIMENTAL TEST RIG

The two-stage unit is represented on figure 1.
The unit was installed to satisfy the experimental requirements, shown in figure 1.
The experimental work was carried at a flow rate of 75.4 l/s and we got group-A results. Then it was carried out at a flow rate equal to 106.8 l/s (group-B). Group-C was at a flow rate of 194.8 l/s. At the final test group-D; at a flow rate of 226.2 l/s; it was noticed that a particles of liquid water (condensate) are carried out by the air and affect the performance of the next units (pre-heater, second cooling coil, and the reheater). This is a resulting effect of the compact construction of the unit and the small spaces between the heat exchangers. Also we noticed that the outlet air carries small water particles. To prevent this effect we may add eliminators, which will increase the pressure drop across the system. So we end our runs at the maximum volume air flow rate of 226.2 l/s.

Fig. 2 Experimental Results (Group A).



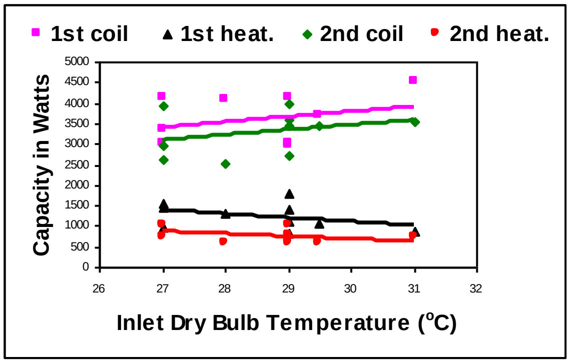


Fig. 3 Experimental Results (Group B).

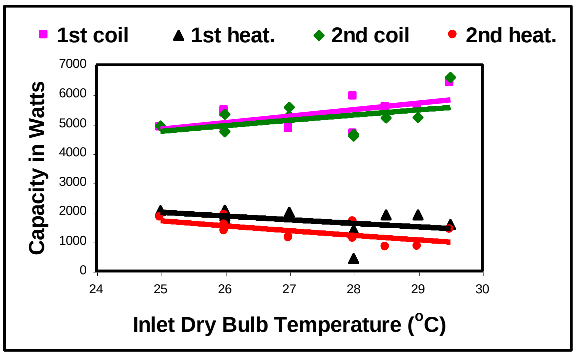


Fig. 4 Experimental Results (Group C).

FUZZY LOGIC CONTROL PROCESS

Using the fuzzy logic control can simulate the HVAC system for the hospital.
The membership functions most commonly used in practice are the trianglar membership functions that have three parameters. Membership function for the Fuzzy sets are shown in figures 5-10, the choice of input variables with different fuzzyness reflects some prior knowledge and provies a control input with different resolution [6].

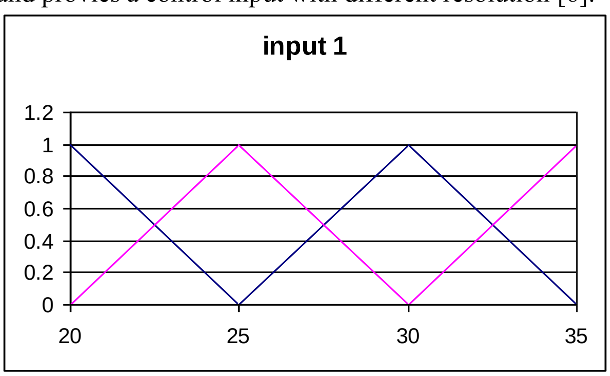


Fig. 5 Membership Function for Input 1.

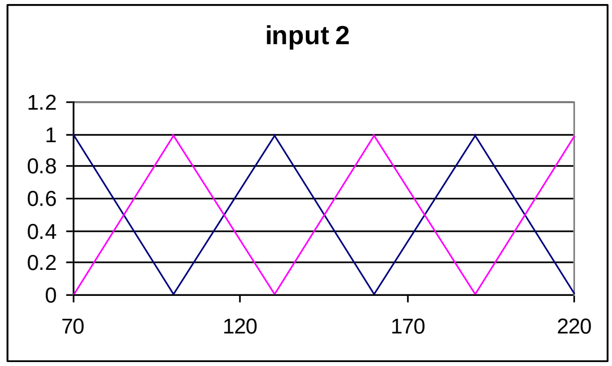


Fig. 6 Membership Function for Input 2

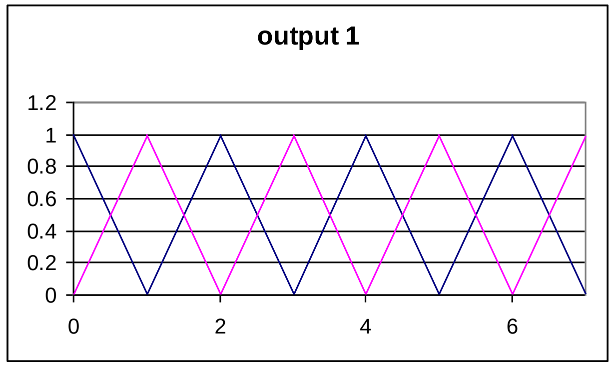


Fig. 7 Membership Function for Output 1

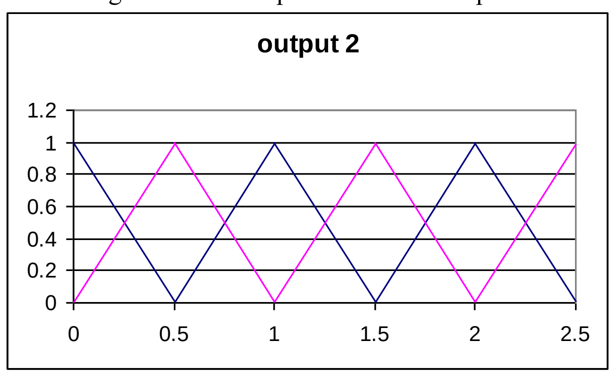


Fig. 8 Membership Function for Output 2

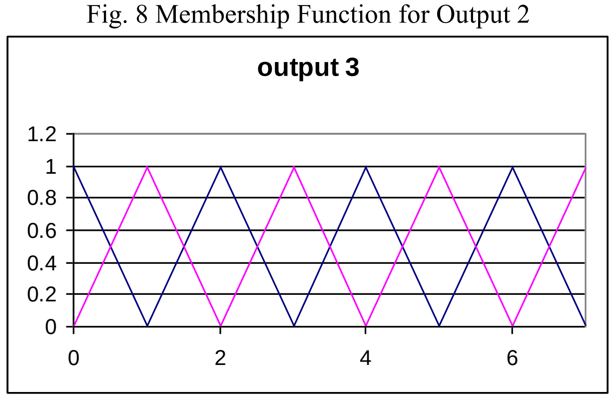


Fig. 9 Membership Function Output 3

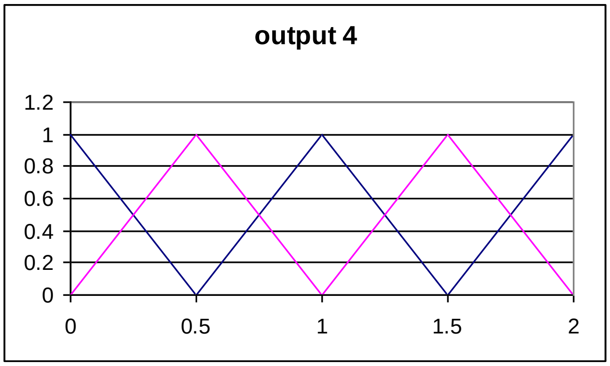


Fig. 10 Membership Function for Output 4

FUZZY LOGIC CONTROL SIMULATION RESULTS

Figures 11-13 show the FLC simulation results for the heating and cooling processes for the different experimental groups.

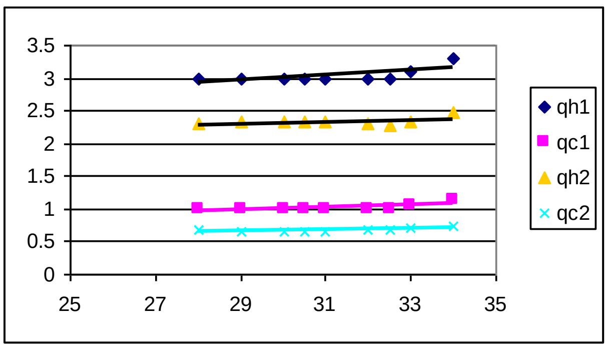


Fig. 11 FLC Results for Group A.

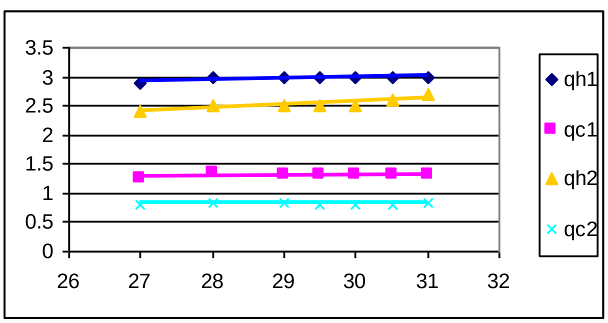


Fig. 12 FLC Results for Group B.

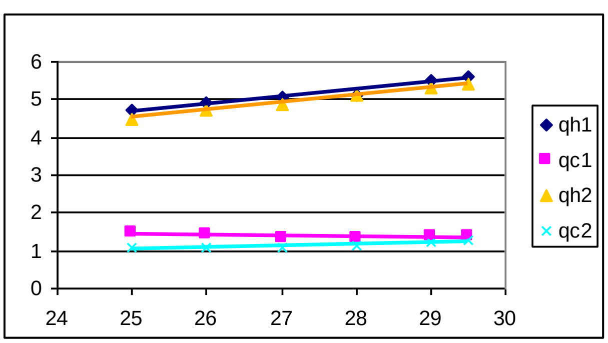


Fig. 13 FLC Results for Group C.

CONCLUSION

In this paper, a fuzzy logic control technique has been proposed to control the processes of the HVAC system to be used for hospital in hot and humid climates.

The design method depends on automatically controlling [opening and closing] the valves and TRIACs of the controlling factors [Heating and cooling elements] associated with the input variables of the fuzzy logic control with the conditions of outside [fresh] air.

Simulation results demonstrate the efficiency of the proposed technique, compared with the experimental results.

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