Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 44 No. 6
June 2023

Real Time Virtual Instrumentation based Control of Climatic Condition in a 4 x 2 MIMO Climatic Chamber through Expert System

S.N.Sivaraj[1*], M.Vijayakarthick[2], N.Vinoth[2], S.Sathishbabu[3]
[1]Department of Electronics & Instrumentation Engineering, Velammal Engineering College, Chennai, India
[2]Department of Instrumentation Engineering, Madras Institute of Technology, Chennai, India
[3]Department of Electronics & Communication Engineering Thanthai Periyar Government Institute of Technology, Vellore, India
Email: *sivarajsn@gmail.com, vijayakarthick@yahoo.co.in, vinothbalaji@rediffmail.com
sathishbabu3575@gmail.com
*Corresponding Author

Abstract-The comfort level of persons in living area, auditorium, patients in hospitals is ensured by -the climatic conditions of the zone. Climatic conditions also have an important impact in the areas such as food preservation unit, stock yards of perishable/non perishable goods. There is a big concern in maintaining the climatic conditions in horticulture for proper growth and yield of plants. The climatic condition[1] of a particular area is ensured mainly by controlling temperature and relative humidity. Today's world utilizes the advance control strategies for achieving a good control over temperature and relative humidity for establishing a environment with comfort climatic conditions. In this work a trail to control temperature and relative humidity is conducted inside an experimental multi input multi output 4 X 2 non linear climatic chamber by means of fuzzy logic controller. The fuzzy logic control system as an expert system is developed using virtual instrumentation software through which the performance of climatic chamber was investigated against disturbances introduced within the standard limits.
Keywords: Fuzzy control, MIMO climatic chamber, temperature and relative humidity control

1. Introduction

Indoor thermal comfort has gained a remarkable importance in the modern days it is widely accepted providing the necessary and satisfactory thermal comfort is very essential; a high importance is given to maintain the temperature and relative humidity of an indoor environment to control the climatic condition of the place. The complexity involved in this process is these two variables are highly interactive with each other by nature[6-9], adjusting any one of these parameters brings out a considerable change in the other and finally brings out a drastic unexpected changes in the climatic condition of the place also increasing the complexity in the implementation of control strategies. The fuzzy control strategy is implemented over the experimental climatic chamber using a control application tool, LabVIEW working with the concepts of virtual instrumentation through proper data acquisition system as interfacing device.

2. Climatic Chamber

Figure 1. The climatic Chamber

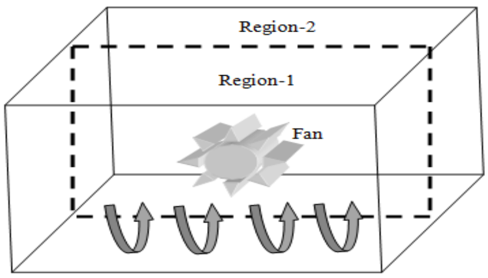

Figure 2. Regions of Climatic chamber

The climatic chamber shown in Figure 1 is a closed experimental chamber designed to observe effect in climatic conditions due to changes in temperature and relative humidity inside air of the chamber also the chamber is featured to experiment and analyze the performances of various new and advanced control strategies to control temperature and relative humidity for achieving the required

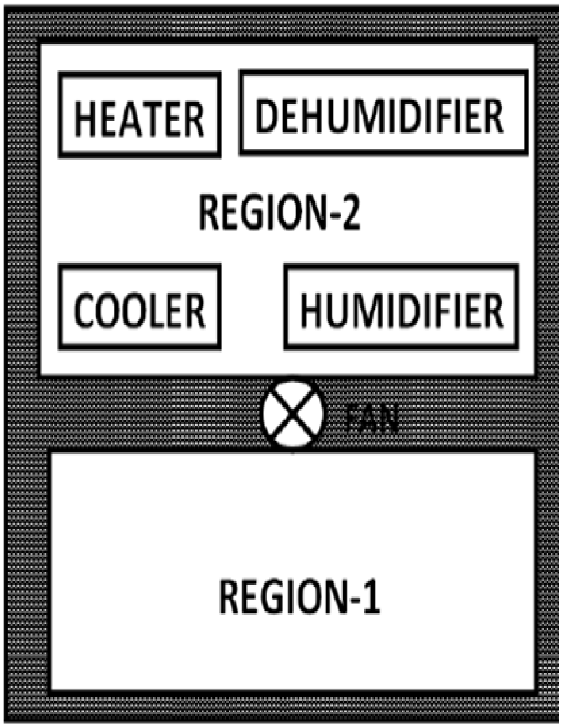

Figure 3. Detailed view of region-2 of chamber

climatic conditions, internally the chamber can be segmented into two regions controlled climatic zone(region-1), and air processing zone(region-2) separated by a metallic wall as shown in Figure 2. The region-2 draws the air from region-1 through a centrifugal fan, process the air for attaining the required climatic condition through its internal units as shown in Figure 3, then passes the air to region-2 through the slit available in the metallic wall. A duct of 8” diameter with a length of 5 meters is associated with the region-1 of the chamber. The duct supplies fresh into the chamber at constant rate by means of a blower operated through a variable frequency drive. The climatic chamber temperature and relative humidity are measured to the readable form by means of Allen Bradley temperature transmitter and relative humidity transmitter. The detailed view of the climatic chamber is as shown in the Figure 3**;** it has four major sections as discussed below.

2.1. Dry Heater Circuit

The dry heater circuit is one that provides temperature raise to the inside air of the chamber. The circuit consists of a dry heating coil of 3Kilo Watts, energized through a thyristor power controller. The fuzzy controller output regulates the thyristor power controller to provide the power input required to the heater. The heater produces heat energy proportional to its input power.

2.2. The Cooling Circuit

The cooling circuit consists of a condensing coil of an air conditioning circuit through which the coolant is circulated to reduce the temperature of air. The coolant flow rate through the coil is regulated by means of a solenoid valve incorporated in the inflow path of the condensing coil. The opening and closing of the solenoid valve is regulated according to the output of the fuzzy controller. The coolant is by passed to the condensing coil without passing through the capillary tubing of the coolant flow path during the solenoid valve closing period.

2.3. The Humidifier Circuit

The humidifier is a open tank boiler with heating coil of 2 Kilo Watts that injects steam into the air available in the region-2 so that the relative humidity value of the region-2 can be made to meet the required specifications. The fuzzy controller associated with the humidifier through its output to the thyristor power control unit regulates the input power to the boiler heating coil to alter the steam generation rate as per the requirement.

2.4. The Dehumidifier circuit

The dehumidifier removes the moisture content by absorbing the water vapour in the air according to the output of the fuzzy logic controller. The removed water vapour are condensed and drained out from the internal regions of the chamber by passing through the drain path associated with the chamber.

3. Data Acquisition System

The data acquisition system of the chamber is established using the analog/digital input/output data acquisition modules developed by National instruments, USA. Temperature and relative humidity values inside the chamber, at the entry and exit level of fresh air duct are measured by means Allen Bradley transmitters with an accuracy of ±1% of the full scale reading and acquired by the control station in the form of (4-20) milli Amperes using a high speed programmable 8 channel analog input module NI 9203 of National instruments. The output from the control station in the form of (4-20) milli Amperes is transmitted to the final control elements of dry heater circuit, boiler circuit, VFD of the blower unit are through a high speed 4 channel analog output module NI 9265 of National instruments, A high speed 8 channel 24Volts logic 100 micro seconds sourcing digital output module NI 9472 configured transfers the digital output generated by the fuzzy logic controller to the final control elements of the cooling and dehumidifying units. The NI 9174 CDAQ chassis encloses all the data acquisition modules and interfaced with the control station through a USB cable as a single point connection. A 24 Volts dc source is provided separately as a standalone unit for fulfilling the power requirements of the transmitter and data acquisition units.

4. Virtual Instrumentation

Control station comprising of four individual fuzzy logic control schemes to control dry heater, cooling unit, humidifier, dehumidifier are developed using National Instruments virtual instrumentation software tool LabVIEW[16-17]. The tool is well equipped with the various instrumentation functional units and developed in an operator friendly manner with a high level of flexibility to develop the control strategies as per the requirement along with the provision to make the necessary time to time modification. The software comprises of a block diagram window that looks like a real control room consisting of all required adjusting knobs and indicators of a control panel and a functional block window that has the wiring and interconnections of the block diagram elements. The fuzzy control logic used for controlling chamber is developed in the function block window by using the tools in the function palette of the functional block window. The block diagram and function block windows are technically interconnected so that changes done in one window will be reflecting immediately in the other window without any delay.

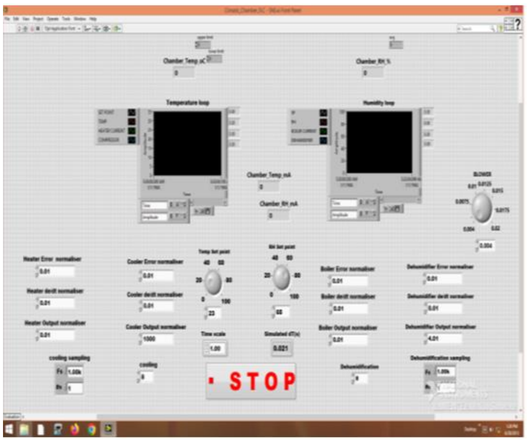

Figure 4. Front Panel Of Fuzzy Control On Climatic Chamber

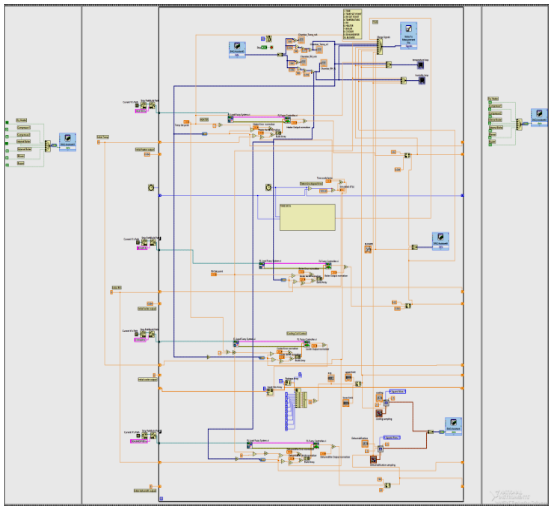

Figure 5. Block diagram of fuzzy control on climatic chamber.

5. Fuzzy Control Scheme

The climatic control inside the climatic chamber is obtained effectively by the implementation of fuzzy logic controller[10]. Four individual fuzzy control loops are incorporated to control the heating, cooling, humidification and dehumidification process of the climatic chamber. The two input fuzzy logic controller implemented for heating and cooling loop considers the error, change in error due to changes in the internal temperature of the chamber as the inputs. The two input fuzzy logic controller[11-15] of humidification and dehumidification loop considers error and change in error due to relative humidity as the inputs. The output of each fuzzy logic controller is based upon the rules framed in its corresponding 5 X 5 Fuzzy Associate Memory (FAM) table. The FAM table of heating and cooling control loop is presented in Table 1 and Table 2. The FAM table for humidifier and dehumidifier control is presented in Table 3 and Table 4 The triangular membership functions are used for defining the fuzzy ranges all the input and output variables operation range is normalized between -1 and 1 while defining the triangular membership functions.

Table 1. FAM unit of heater control unit

e, ce	NES	NEB	ZO	POS	POB
NES	ZO	ZO	POS	POS	ZO
NEB	NES	NES	NES	ZO	POS
ZO	NES	NES	ZO	POS	POS
POS	POS	ZO	ZO	POB	POB
POB	POS	ZO	POS	POB	POB

Table 2. FAM unit of cooler control unit

e, ce	NES	NEB	ZO	POS	POB
NES	POS	POS	POS	POS	ZO
NEB	NES	ZO	NES	ZO	POS
ZO	NES	NEB	ZO	POS	ZO
POS	POS	ZO	ZO	POB	POB
POB	POS	ZO	POS	POB	POS

Table 3. FAM unit of humidifier control unit

e, ce	NES	NEB	ZO	POS	POB
NES	ZO	ZO	POS	POS	POS
NEB	NES	NES	NES	ZO	POS
ZO	NES	NEB	ZO	POS	POS
POS	POS	NES	ZO	ZO	POB
POB	POS	ZO	POS	POB	POS

Table 4. FAM unit of dehumidifier control unit

e, ce	NES	NEB	ZO	POS	POB
NES	NEB	ZO	POS	ZO	ZO
NEB	NES	NES	NES	ZO	ZO
ZO	NES	NES	ZO	POS	POS
POS	POS	POS	ZO	POB	POS
POB	POS	ZO	POS	POB	POB

The controller output of the cooling and dehumidification loop is fed as duty cycle input to the digital pulses of the solenoid valve acting as the final control element of the loops. The controller output of the heater and humidifier drives the thyristor power controller of the loops such that the power input to the heating coil of the loops is regulated to maintain temperature and relative humidity. The block diagram and functional diagram view of fuzzy logic control scheme implemented using LabVIEW is shown in Figure 4 and Figure 5 respectively.

6. Results

The results are obtained with a constant fresh air flow into the chamber region-1 as a continuous disturbance Figure 6 shows the response of temperature loop for a set point of 23°C and relative humidity for a set point of 65%. Figure 7 shows the ability of the fuzzy logic controller in set point tracking for temperature and relative humidity loops. Figure 8 shows the fuzzy controller effectiveness in eliminating the effect of interaction of temperature and relative humidity when the set point of temperature alone is altered.

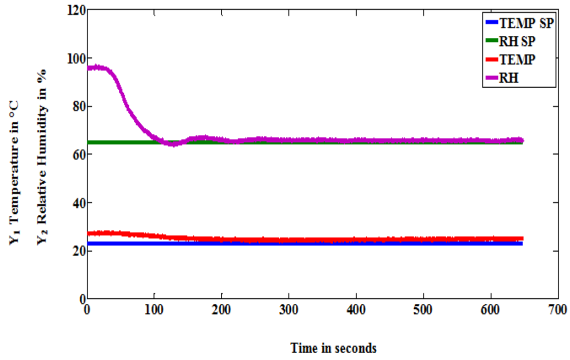

Figure 6. Closed loop response of temperature and relative humidity control loop

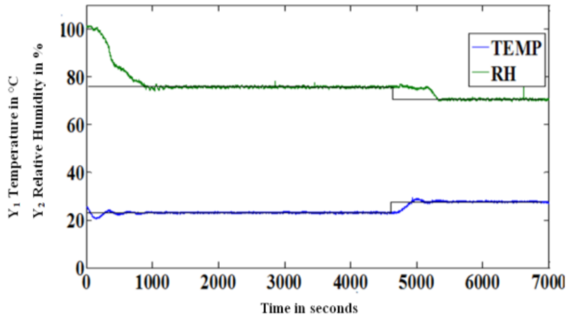

Figure 7. Setpoint tracking of temperature and relative humidity loop

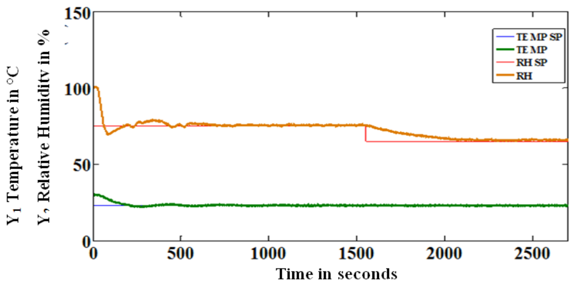

Figure 8. Elimination of interaction between temperature and relative humidity through fuzzy controller

7. Conclusions

The fuzzy logic controller regulates the temperature and relative humidity inside the climatic chamber to maintain the desired climatic conditions through virtual instrumentation software LabVIEW. The control system implementation through virtual instrumentation makes the system cost effective. The responses are found to be improved with lesser rise time, settling time and energy consumption when the chamber behavior is observed with the conventional controller. The fuzziness of the fuzzy controller eliminates the interaction between the temperature and relative humidity and gives a highly effective control over the climatic conditions against the disturbances of the climatic chamber.

Acknowledgements
The authors would like to thank All India Council for Technical Education, an apex body of Government of India for funding this research work under research promotion scheme 20/AICTE/RIFD/RPS (POLICY-III) 122/2012-13.

References
[1] Sivaraj, S.N., and N. Bharathi. "Multivariable control in a multi input multi output climatic chamber to establish climatic comfort inside the chamber", 2015 *International Conference on Electrical Electronics Signals Communication and Optimization (EESCO),* 2015.
[2] Janprom, K., Permpoonsinsup, W. and Wangnipparnto, S., Intelligent tuning of PID using metaheuristic optimization for temperature and relative humidity control of comfortable rooms. *Journal of Control Science and Engineering,* 2020.
[3] Biryukov, J., Boydston, J.A., Dunning, R.A., Yeager, J.J., Wood, S., Reese, A.L., Ferris, A., Miller, D., Weaver, W., Zeitouni, N.E. and Phillips, A., Increasing temperature and relative humidity accelerates inactivation of SARS-CoV-2 on surfaces. *MSphere*, 2020. 5(4), pp.e00441-20
[4] Chai, Q., Li, Y., Li, X., Wu, W., Peng, H., Jia, R. and Sun, Q.,. Assessment of variation in paddy microbial communities under different storage temperatures and relative humidity by Illumina sequencing analysis. *Food Research International*, 2019 126, p.108581.
[5] Gutierrez, Johan S. Malpica, Ismael A. Fernández Peña, and Fernando Martínez Santa. "Design, construction and implementation of relative humidity and temperature climatic chamber for metrology laboratory." *Journal of Physics: Conference Series*. 2021,Vol. 2135. No. 1.
[6] X. Zeng and C. Yu, "Multivariable IMC-PID within air-conditioned room temperature and relative humidity control system," *Proceedings of the 33rd Chinese Control Conference*, 2014, pp. 3609-3613.
[7] C. Rentel-Gomez and M. Velez-Reyes, "Decoupled control of temperature and relative humidity using a variable-air-volume HVAC system and non-interacting control," *Proceedings of the 2001 IEEE International Conference on Control Applications (CCA'01) (Cat. No.01CH37204)*, 2001, pp. 1147-1151
[8] M. Zeyad *et al*., "Design and Implementation of Temperature & Relative Humidity Control System for Poultry Farm," *International Conference on Computational Performance Evaluation (ComPE)*, 2020, pp. 189-193.
[9] ASHRAE@ Handbook, "Heating, Ventilating, and Air-conditioning APLICATIONS ", 179 1 Tullie Circle, N.E., Atlanta, GA. SI ed, 1999.
[10] Purwanto, F.H., Utami, E. and Pramono, E., Design of server room temperature and humidity control system using fuzzy logic based on microcontroller. *IEEE. International Conference on Information and Communications Technology (ICOIACT)* March 2018, pp. 390-395.
[11] Benyezza, H., Bouhedda, M., Zerhouni, M.C., Boudjemaa, M. and Dura, S.A., Fuzzy greenhouse temperature and humidity control based on Arduino *IEEE International Conference on Applied Smart Systems (ICASS)* November 2018 pp. 1-6.
[12] Agustianto, K., Wardana, R., Destarianto, P., Mulyadi, E. and Wiryawan, I.G., 2021, March. Development of automatic temperature and humidity control system in kumbung (oyster mushroom) using fuzzy logic controller. *Earth and Environmental Science* Vol. 672, No. 1, p. 012090.
[13] Yavuz, Ü.S.E.R. and Cumali, K.A.R.A., 2019. Real-Time Communication between S7-1200 PLC and Matlab/Simulink and a Fuzzy Logic Temperature Humidity Control Application. *Scientific Journal of Mehmet Akif Ersoy University*, *2*(1), pp.7-14.
[14] Waheed, S.R., Adnan, M.M., Suaib, N.M. and Rahim, M.S.M., Fuzzy logic controller for classroom air conditioner. *Journal of Physics: Conference Series,* 2020 Vol. 1484, No. 1, p. 012018.
[15] Ali, R.B., Bouadila, S. and Mami, A.,. Development of a Fuzzy Logic Controller applied to an agricultural greenhouse experimentally validated. *Applied Thermal Engineering,* 141, pp.798-810.
[16] Khan, M.A.S., Rajkumar, R.K., Aravind, C.V., Wong, Y.W. and Bin Romli, M.I.F., 2020. A LabVIEW-based real-time GUI for switched controlled energy harvesting circuit for low voltage application. *IETE Journal of Research*, *66*(5), pp.720-730.
[17] Zhang, L., Yao, Y. and Xu, L., 2020. Study on LabVIEW-based Aviation BLDCM Control System. *Materials Science and Engineering* Vol. 751, No. 1, p. 012012.