

FUZZY LOGIC CONTROL OF DOMESTIC AIR-CONDITIONING SYSTEM FOR ENERGY SAVINGS

Shodiya, S.^{1a}, Mukhtar, U.A.^{1b}, Abdulrazaq, A.A.^{2c}

¹*Department of Mechanical Engineering, Faculty of Engineering, University of Maiduguri (UNIMAID), Maiduguri, Borno, Nigeria.*

²*Department of Computer Engineering, Faculty of Engineering, University of Maiduguri (UNIMAID), Maiduguri, Borno, Nigeria*

E-mail: sulaimonshodiya@yahoo.com^a; umuktara@yahoo.co.uk^b; ibnrazaaq@gmail.com^c

Abstract

There has been a rising concern in improving the energy saving in building. Heating ventilation and air condition system is the biggest consumer of energy in building. In this paper, fuzzy logic control (FLC) of a domestic air conditioning (AC) system for efficient energy operation and indoor thermal comfort is carried out. A design has been proposed using five input and two output parameters. The input variables are the temperature of user, temperature difference [difference between the actual room temperature and the temperature provided by the user], number of occupant, time of the day and dew point temperature while the output variables are the compressor speed and the mode of operation. By considering various input parameters and applying Fuzzy Logic to the Air Conditioner, the input parameters can be greatly modified and thus reducing the electrical energy intake of the AC while utilizing all available resources in an efficient manner. For better implementation, the climatic condition of hot semi Arid region namely Maiduguri area of Borno state, Nigeria is considered. Maiduguri being in the desert area, the values of temperature is high and humidity is low in comparison to coastal areas of Nigeria. The simulation results showed that 35.2, 30.6 and 54.9% of electrical energy can be saved in the morning, afternoon and night respectively when the FLC is put into use.

Keywords: Fuzzy logic controller, Domestic Air-conditioner, Energy saving, compressor speed, indoor thermal comfort.

1. INTRODUCTION

A large amount of energy is being used by the building sector, and in the buildings, energy use by Heating, Ventilation and Air-Conditioning (HVAC) systems is dominant. For effective use of energy, a study on the performance and operational strategies of HVAC systems is of paramount importance[1]. Previous studies have shown that by using control strategies on the parameters of HVAC systems, minimum energy consumption could be obtained and consequently high performance of the systems could be achieved.

There are various approaches used in controlling HVAC systems for indoor building environments. These control strategies are divided into conventional methods and

computational Intelligence techniques [1-8]. Under the conventional method, The Proportional-Integral-Derivative (PID) control of HVAC system with two zones of different properties was studied[1]. In their study, to minimize the system error, the parameters of PID were obtained but the error were not totally removed. Nevertheless, there is an improvement using these controllers. Generally, instability of the system results from inappropriate choice of the gains in the PID controller. As a result, Engineers resort to finding the optimal [1, 2, 7], predictive, or adaptive control techniques[4].

In the computational intelligence technique of the systems, no mathematical model of the system is required. Discussion on practical applications of these intelligent controls on HVAC systems is ongoing. The main goal of the discussion is performance improvement over conventional control method[3, 5]. Examples of the intelligence techniques are fuzzy logic, expert systems, neural networks, genetic algorithm etc.

Fuzzy logic is a type of artificial intelligence that deals with reasoning that is approximate rather than fixed and exact [8]. One of the benefits of fuzzy control is that it can be easily implemented on a standard computer. Unlike in the traditional logic theory, where two-valued logic are available i.e true or false, fuzzy logic variables can have a truth value between 0 and 1. Likewise, Fuzzy logic can also handle the idea of partial truth. In that case, the truth value may vary between completely true and completely false. Unquestionably, using fuzzy logic algorithm, machines could be enabled to understand and respond to vague human concept such as hot, cold, large, small, etc

Due to inadequate supply of electrical energy in Nigeria, it is not long before we have to think of efficient ways of reducing electrical power consumption, especially in devices that are specifically designed for heating or cooling purposes because these are the devices that have the maximum power consumption.

In this paper we have devised a scheme implementing Fuzzy Logic in a domestic Air-Conditioning system. With the help of this logic, the Air-Conditioner would assess the environmental factors like temperature of user, number of occupant, time of the day and dew point temperature, etc and thereby provide comfortable levels of cooling and optimized electricity consumption by controlling the compressor speed. The main idea of designing the fuzzy logic controller is to maximize energy saving for an air conditioning system application through variable speed drive control of the compressor.

2.0 METHODOLOGY

2.1 An Air-Conditioner

An air conditioner (AC) is an appliance, system, or mechanism designed to simultaneously extract heat and dehumidify an area. The cooling is done using a simple refrigeration cycle which consists basically of the following equipment: Compressor, Condenser, Evaporator and an Expansion device[9]. The electrical energy consumption of the system is in the compressor.

2.2 Fuzzy Logic Controller (FLC)

In the FLC, a set of basic rules is designed to form a decision table. The table is made up of the input variables such as the temperature of user (Tu), temperature difference (Td) number of occupant (Noc), time of the day(Tod) and dew point temperature (Dpt)while the output variables are the Speed of Compressor (Soc)and the mode of operation (Moo). All the rules in the decision table were based on the user's experience.

2.3 Fuzzy Input Variables

2.3.1 Temperature of User (Tu)

Temperature of User (Tu) is the temperature supplied by the user using the remote control or thermostat. According to the data obtained from the Nigerian meteorological department (NIMET)[10], Maiduguri, Borno state, the range of the temperature used vary between 18°C and 32°C. So the user set the temperature accordingly using the remote control or thermostat. Membership functions for Tu is shown in Fig. 1. The values taken into consideration during the membership Function are the values approximated from the data provided by NIMET.

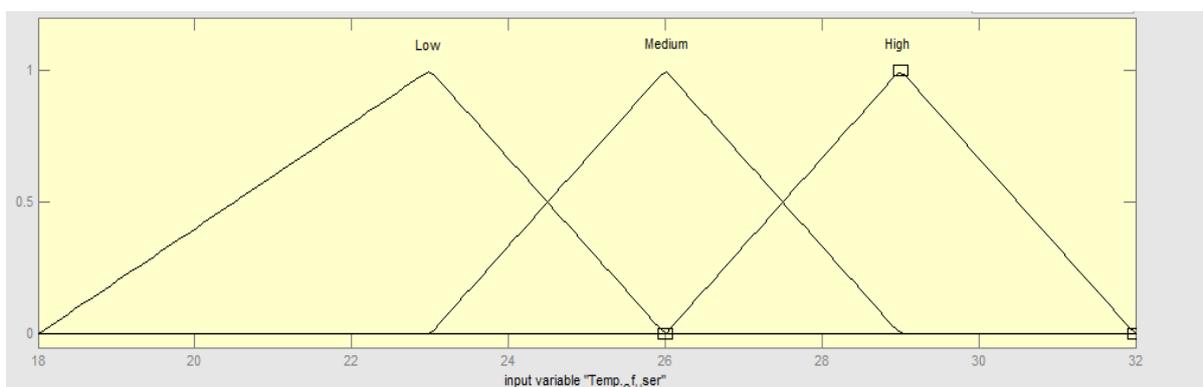


Fig. 1: Temperature of user (Tu) Membership Functions

2.3.2 Temperature Difference (Td)

Temperature Difference (Td) is the difference between the actual room temperature and that of the one provided by the user (Tu). In this study, the range is between -5C to +5C. The system will switch off once it is out of this range since this AC cannot work as a heat pump. Membership functions for Td is shown in Fig. 2

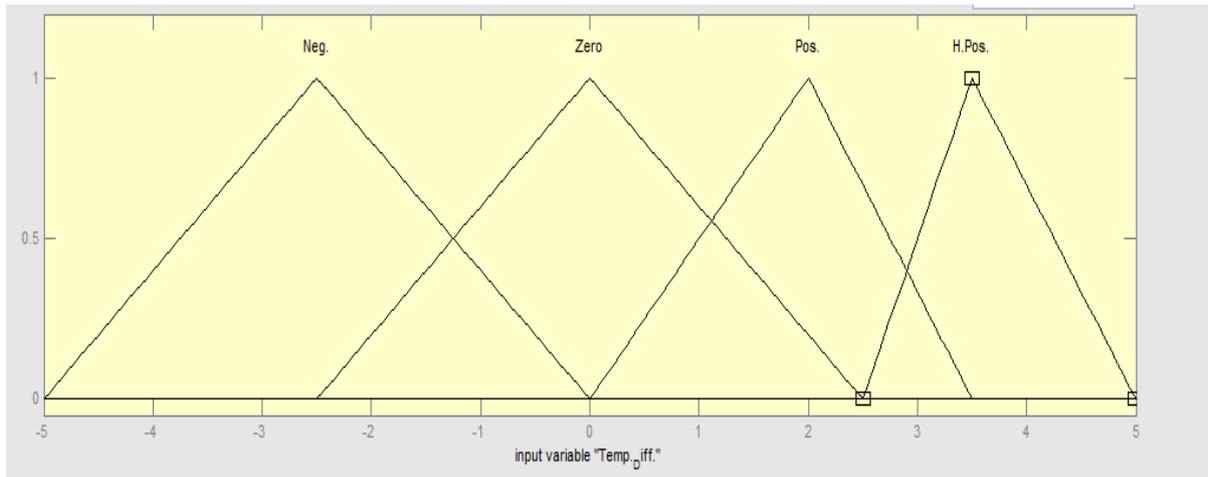


Fig. 2: Temperature Difference (Td) Membership Functions

2.3.3 Number of Occupants (Noc)

Number of occupants is the number of people in the air conditioned room. The range of people will decide the level of occupancy as low, medium or high. However, if there is nobody in the room, the compressor fan remains off. These studies take into account the condition in a medium sized room (doestic air conditioner). In this case, the level of occupancy is taken to be between 1 -10. Membership functions for Noc is shown in Fig. 3.

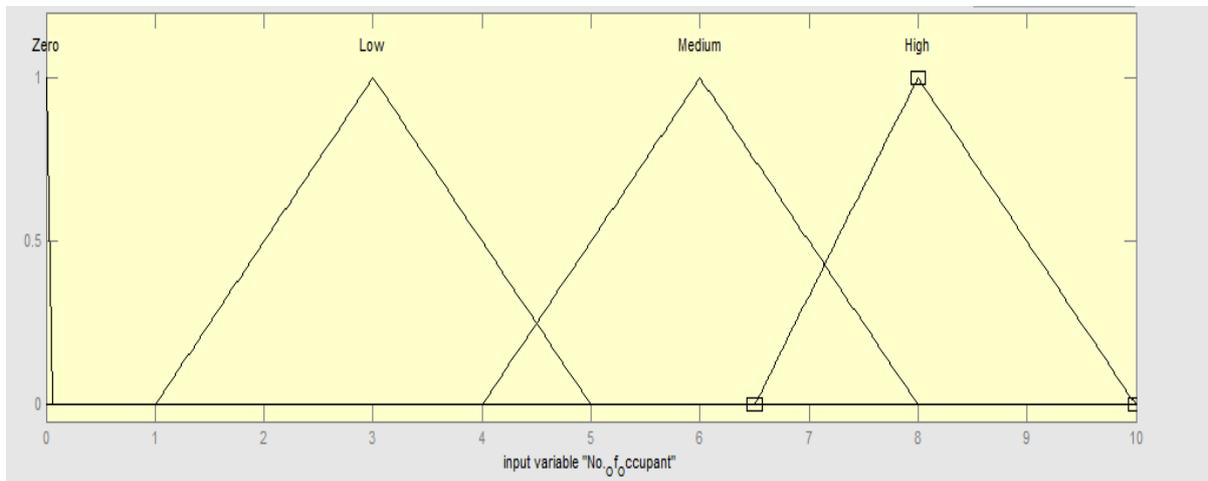


Fig 3: Number of Occupant (Noc) Membership Functions

2.3.4 Time of Day (Tod)

Time of Day is the time during which the AC would be functioning. The data obtained from NIMET[10] showed that the temperature and dew point values differ significantly during morning/night time with that of afternoon time. Considering this difference, the optimum cooling and power consumption requirement can be chosen. In this study, 00:00 –11:00 is taken as morning, 10:00 - 19:00 as afternoon, and 17:00-24:00as night. It should be noted that values of Temperature of user and Dew Point Temperature are adjusted according to the Time of Day of operation of the AC. Membership functions for Tod is shown in Fig. 4.

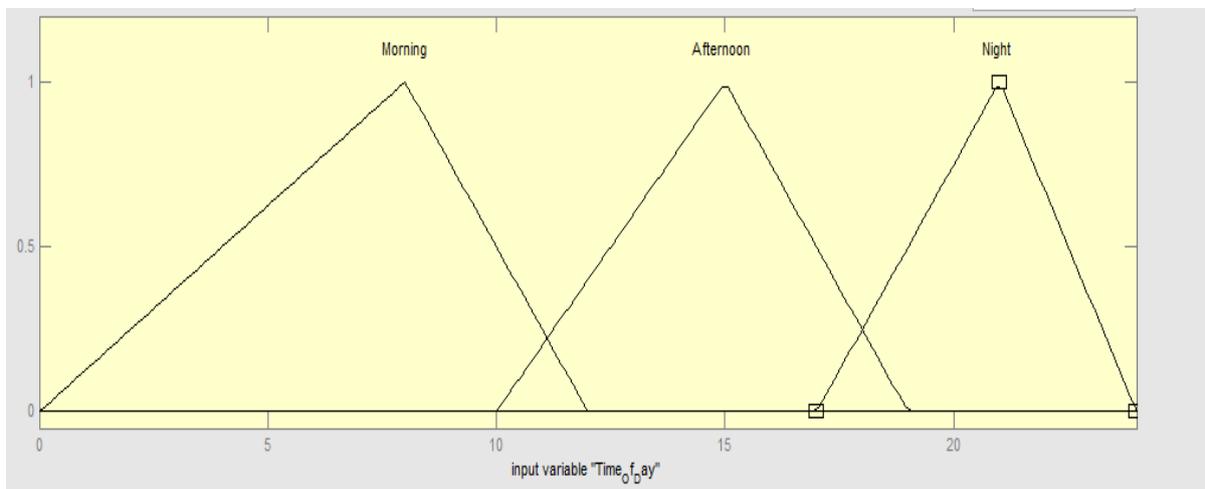


Fig. 4: Time of Day (Tod) Membership Functions

2.3.5 Dew Point Temperature (Dpt)

Dew point temperature is a temperature in which water vapour present in the air condenses to form either dew, frost, or water droplets at constant pressure. Generally, the human response to changes in dew point temperature has been established [11]. A standard relationship between the Dew Point temperature and Human Reaction is given in Table 1. Based on this table, the membership function for Dew Point temperature is determined and is given in Fig 5.

Table 1: Standard Relation between Dew point Temperature and Human Reaction

Dew Point Temperature	Human Reaction
28	Oppressive
26	Sticky
25	Humid
24	Comfortable
23	Refreshing

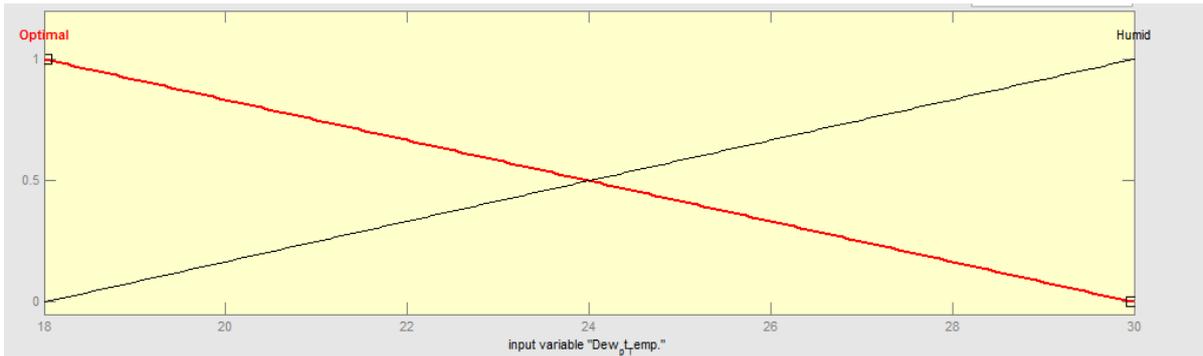


Fig. 5: Dew Point Temperature (Dpt) Membership Functions

2.4 Fuzzy Output Variables

The various outputs of the Fuzzy Controller are:

2.4.1 Compressor Speed (Soc)

The speed of compressor is varied between 30 to 100%. This speed of the compressor depends on the power consumption of the AC system. The lower the speed, the lower the power consumption and the higher the speed, the higher the power consumption. The FLC is designed to provide comfortable levels of cooling and optimized electricity consumption by controlling the speed of compressor. Membership functions for Soc is shown in Fig. 6.

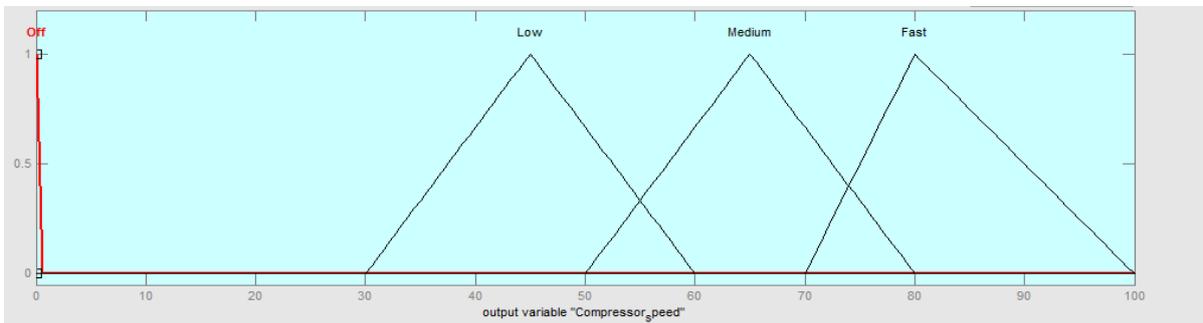


Fig. 6: Speed of Compressor (Soc) Member Function

2.4.2 Mode of Operation (Moo)

Air conditioning system can extract heat from the space and absorb the humid content in the space to be conditioned simultaneously. By extracting the heat, it will regulate the air to release cool air to the space. However, it will absorb the moisture content (dehumidifier) of the air by passing dry air into the space. It should be noted that this process of dehumidifier does not increase the temperature of the room. Also, setting preference of the dehumidifier is not performed by the user. It is performed implicitly by the AC. A greater efficiency is achieved when this parameter is considered. Membership functions for Moo are shown in Fig. 7.

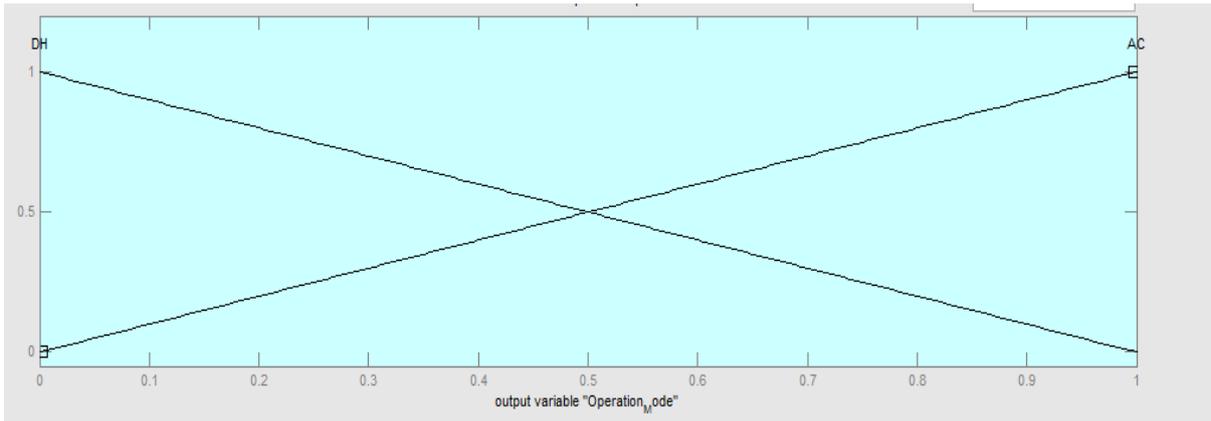


Fig 7: Mode of Operation (Moo) Membership Functions

2.5 Implementation of The Fuzzy Logic Controller

This paper used MATLAB 7.12.0.635 version for its implementation. The Fuzzy rules were designed and the Rule Editor generates rules for all combinations of selected input variable and the corresponding output variables. The rules are formed keeping in mind heuristic relationship between input and output parameters. The rules were defined by selecting the right sequence in the If-then sequence. The Fuzzy base rules are shown in Fig. 8.

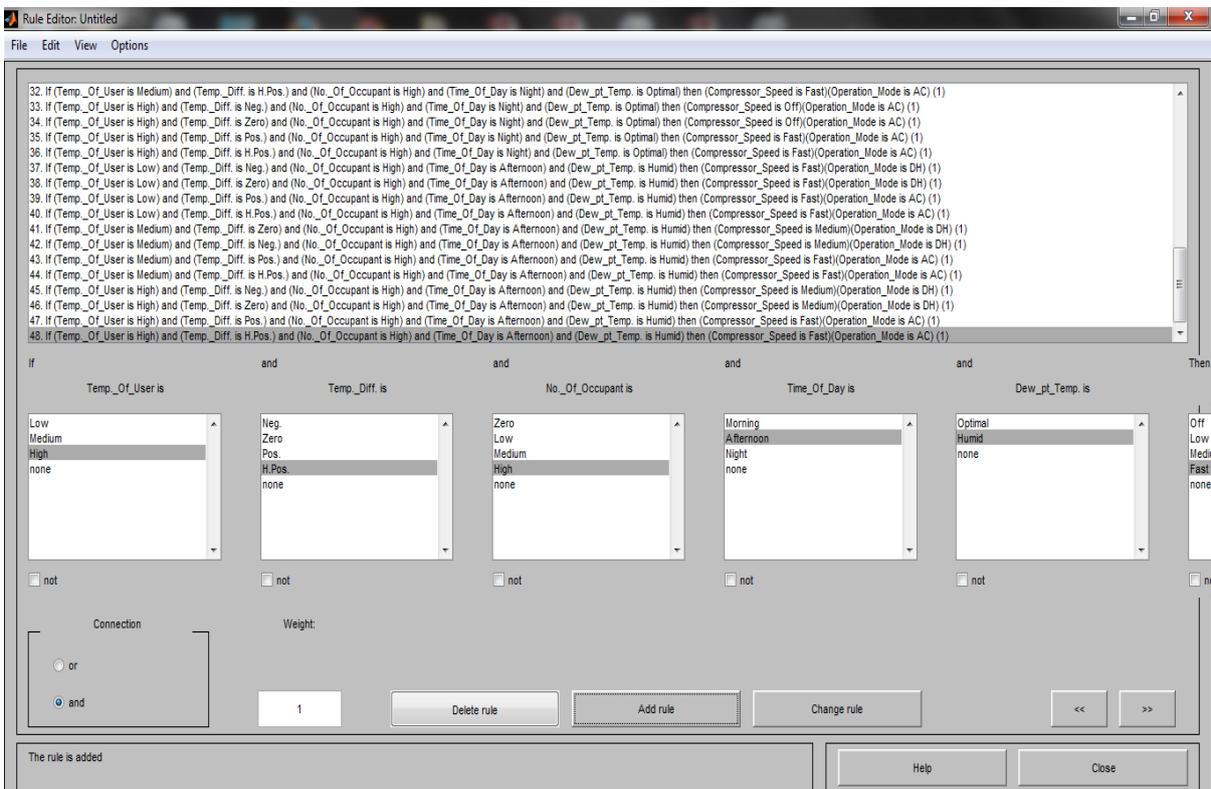


Fig 8: Fuzzy Base Rules

3 RESULTS AND DISCUSSION

3.1 Simulated Results

The Surface Viewer of the Fuzzy Logic Toolbox in the MATLAB software was used to generate the following Graphs: 3D graphical results of various input variables and corresponding output variable are shown in Fig. 9 - 12.

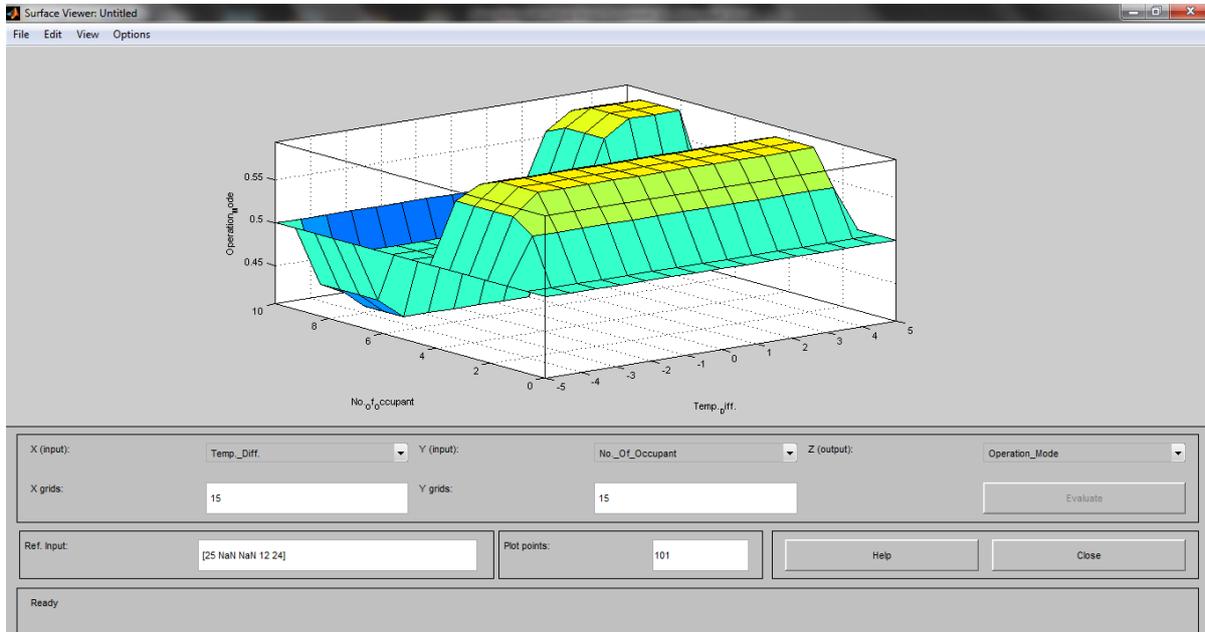


Fig 9: Gradient graph of Temp. Diff. VS No. of occupants VS Operation mode

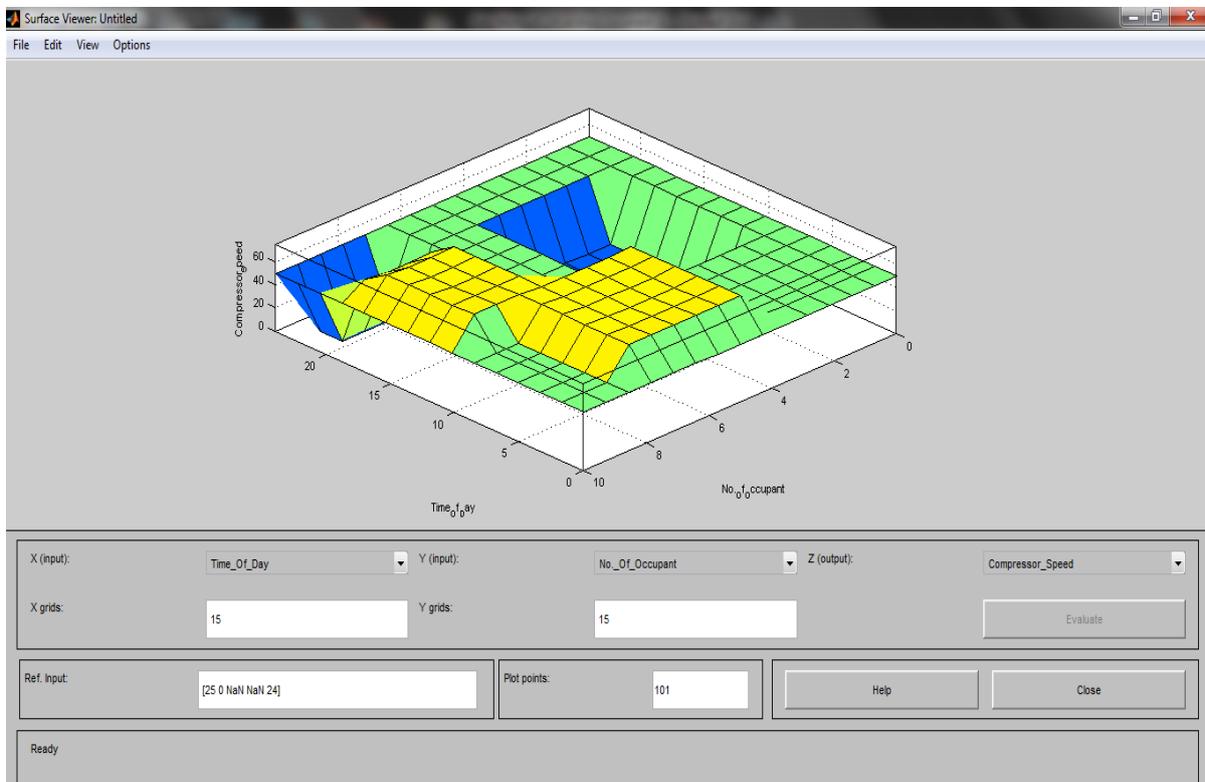


Fig 10: Gradient graph of No. of occupants VS Time of Day VS Compressor speed

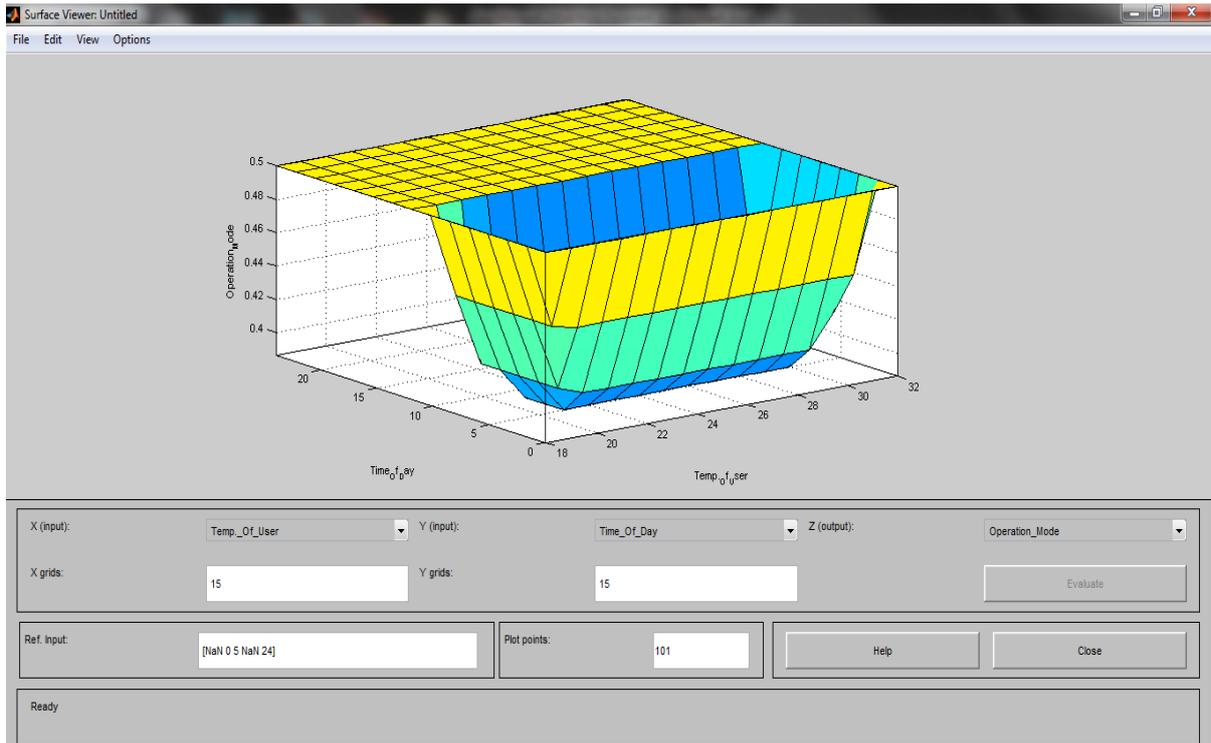


Fig 11: Gradient graph of Temp. of user VS Time of Day VS Operation mode

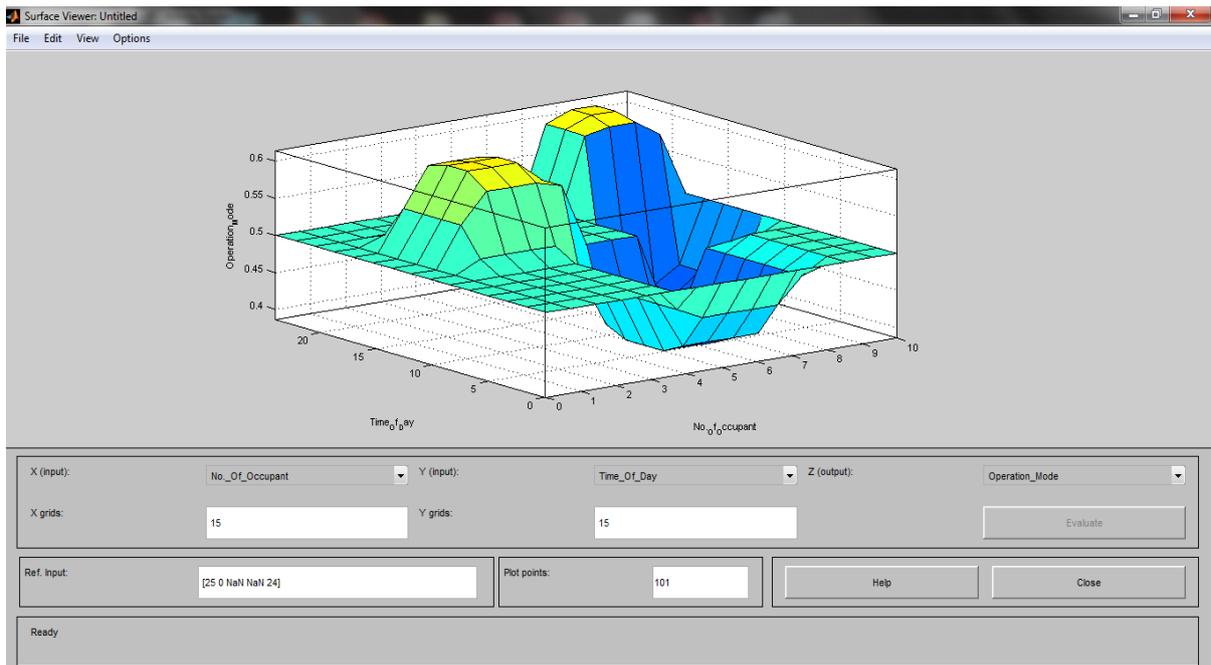


Fig 12: Gradient graph of No. of occupants VS Time of Day VS Operation mode

3.2 The Rule Viewer

In order to apply the FLC designed in this paper, the rule viewer is used.

The Rule Viewer as shown in Fig. 13 gives us the insight about the application of the fuzzy member function to input values of the simulation. For example, some set of inputs variables were taken. Case I: $T_u = 22$, $T_d = 2$, $N_{oc} = 7$, $T_{od} = 08:00$ hours, $D_{pt} = 24$ and the

corresponding outputs are Soc=64.8%, Moo=0.646. Case II: Tu =22, Td =2, Noc =7, Tod = 12:00 hours, Dpt =24 and the corresponding outputs are Soc=69.4%, Moo =0.646. Case III: Tu =22, Td =2, Noc =7, Tod= 20:00 hours, Dpt =24 and the corresponding outputs are Soc=45.1%, Moo=0.646.

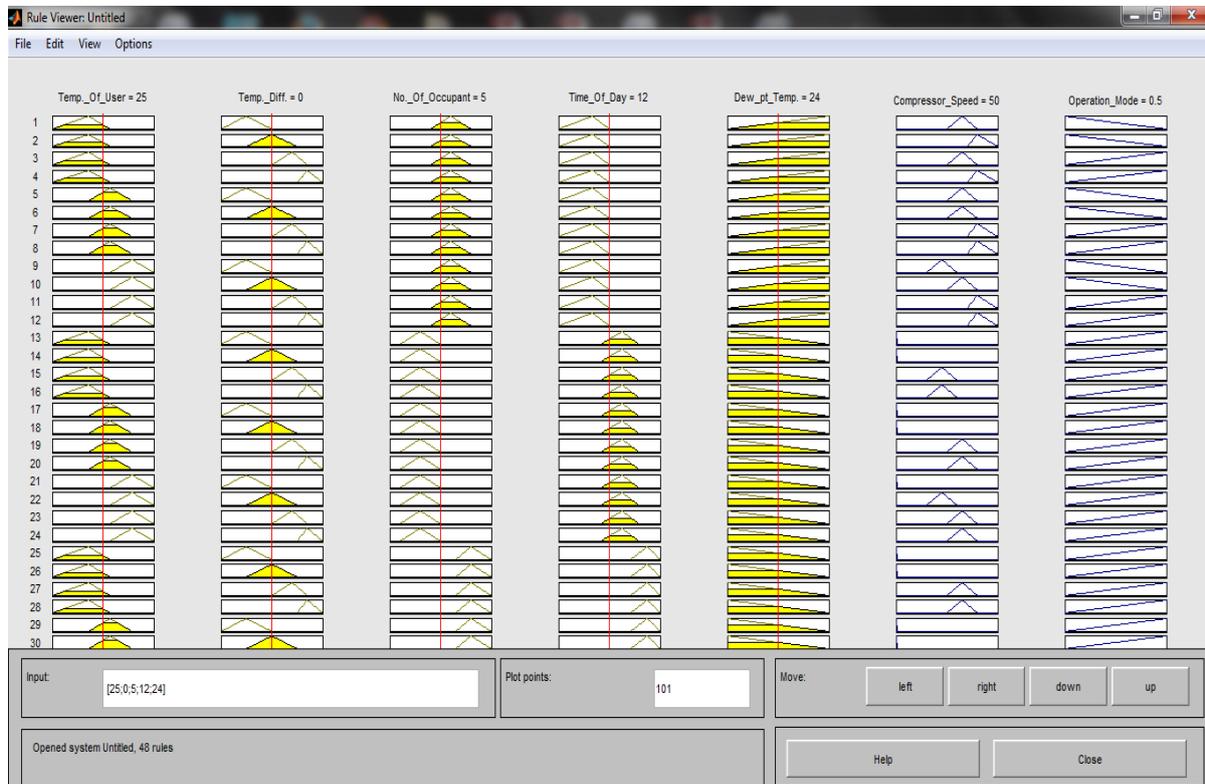


Fig 13: Fuzzy Rule Viewer

4. CONCLUSION

A FLC has been designed to control the speed of compressor and also maintain the set point temperature. When the room was thermally loaded with people, the controller acts in such a way that the set point temperature was reached again. The energy consumption changes when the speed of compressor changes. When the speed of compressor increases, the room temperature decreases. The results also showed that the designed fuzzy rule produced a satisfactory solution in terms of energy savings for the room employed. The paper showed the advantage of Fuzzy logic in solving difficult problems in AC that cannot be analytically solved. Using our intuition in terms of linguistic variables, an optimally performing AC can be designed. By putting this FLC design into use, 40.23% of electrical energy can be saved.

REFERENCES

1. Ashrae-Handbook, *HVAC Systems and Equipment*. ASHRAE Publications, 2008.
2. Dounis, A.I. and C. Caraiscos, *Advanced control systems engineering for energy and comfort management in a building environment—a review*. *Renew. Sustain. Energy Rev.*, 2009. **13**: p. 1246–1261.
3. Etik, N., N. Allahverdi, I.U. Sert, and I. Saritas, *Fuzzy expert system design for operating room air-condition control systems*. *Expert Syst. Appl.*, 2009. **36**: p. 9753–9758.
4. Huang, G., S. Wang, and X. Xu, *A robust model predictive control strategy for improving the control performance of airconditioning systems*. *Energy Convers. Manage.*, 2009. **50**: p. 2650–2658.
5. Navale, R.L. and R.M. Nelson, *Use of genetic algorithms and evolutionary strategies to develop an adaptive fuzzy logic controller for a cooling coil comparison of the AFLC with a standard PID controller*. *Energy Build*, 2012. **45**: p. 169–180.
6. Shodiya, S., N. AffandiMohd, N. Henry, A.A. Azhar, O. Muchamad, and Sumeru, *Energy Analysis of Split Air Conditioning System Using Variable Speed Drive*. *Applied Mechanics and Materials*, 2016. **819**: p. 212-215.
7. Shodiya, S., N. Henry, A.D. Afiq, A.A. Azhar, A. Ulul, and Sumeru, *Energy Efficiency of A Variable Speed of The Centralized Air Conditioning System Using PID Controller*. *Jurnal Teknologi*, 2016. **78(4-8)**: p. 65–71.
8. Siham, A.M.A., A.A.Q. Wadea, K. Ahmed, and A.A.A. Ibrahim, *Fuzzy Expert Systems to Control the Heating, Ventilating and Air Conditioning (HVAC) Systems*. *International Journal of Engineering Research & Technology*, 2015. **4(8)**: p. 808 - 815.
9. Shodiya, S., A.A. Azhar, N. Henry, and N.D. Amer, *Simulation of Alternative Refrigerant Characteristics Using Artificial Neural Network in Air-Conditioning System*. *The 3rd International Conference on Construction Industry*, 2012: p. 105 -114.
10. NIMET, Nigerian Meteorological Department, Maiduguri, Borno State, Nigeria.
11. Indian Meteorological Department, Bhubhaneswar, Odisha, Government of India.