INTERNATIONAL JOURNAL OF APPLIED TECHNOLOGY RESEARCH
2022, VOL. 3, NO. 2, pp. 91-105
https://ijatr.polban.ac.id/

Energy Savings for Air Conditioning System Using Fuzzy Logic Controller Design for Northeastern Nigeria

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Received August 4, 2022; Revised September 1, 2022; Accepted September 1, 2022; Published October 1, 2022

ABSTRACT
Efficient air cooling in an air conditioning system minimizes power consumption. The air conditioning system is considered one of the home appliances in which a massive amount of electrical energy is recorded, especially in the urban area. In this work, the fuzzy logic controller is designed to save energy for northeastern Nigeria using six and two input and output parameters respectively. The input parameters consist of the temperature of the user, temperature difference, number of occupants, time of the day, dew point temperature, and weather conditions. The output parameters consist of compressor speed and operation mode. The controller performance was simulated. The controller is designed in such a way that it can control the compressor speed leading to energy savings, and the operation mode to optimize humidity conditions, and when the room gets hot, it switches to air conditioning. The simulated result showed that a good percentage of electrical power could be saved when fuzzy logic is utilized.

KEYWORDS
Air conditioning
Control
Energy system
Fuzzy logic
Savings

INTRODUCTION

With the increased usage of cooling devices in Nigeria, air conditionings usages are becoming an important part of our daily life. Air conditioning system significantly affects the electrical grid by consuming power in residential buildings. Precise prediction of air conditioner variations can improve the stability of the grid [1]. Energy consumption in an air conditioning system is a key area to concentrate on reducing energy consumption to ensure thermal comfort when designing the air conditioning system. With the increase in the usage of air conditioners, there is a simultaneous increase in electrical power consumption [2] 90% of energy is consumed by air conditioning systems [3]. When input variables are considered, the functioning of the AC can be modified greatly and minimize the power consumption in AC compressor/fan while making good use of available resources in an effective way [2]. Efficient management of the cost and energy of

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a building's thermal properties requires heating, ventilation, and air conditioning (HVAC) systems controllers to be working in the best settings [4].

Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact [2], [5]. Fuzzification, inference mechanism, Fuzzy rule base, and defuzzification are fuzzy logic control input and output major components [6].

Fuzzy Logic Control (FLC) saves energy and performs more desirable than the other control systems studied; it makes an enormous change in the development of uncertainty in artificial intelligence systems. FLC is used widely in uncertainty and robust development [7]. 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 to use [8]d.

Due to the lack of power supply in Nigeria, there is a need to think of a better way of reducing energy consumption in our homes, especially for devices that are mainly designed for cooling and heating purposes due to their high-power consumption.

This work is focused on energy savings using FLC. The main aim of designing the controller is to optimize energy savings by controlling the speed of the compressor for an air conditioning system.

MATERIAL AND METHODS

Air Conditioner

Air conditioning is the most important aspect of increasing the thermal comfort and working efficiency of a human being. In an air conditioner, the compressor is the component that alone consumes 90% of the total energy consumption [9].

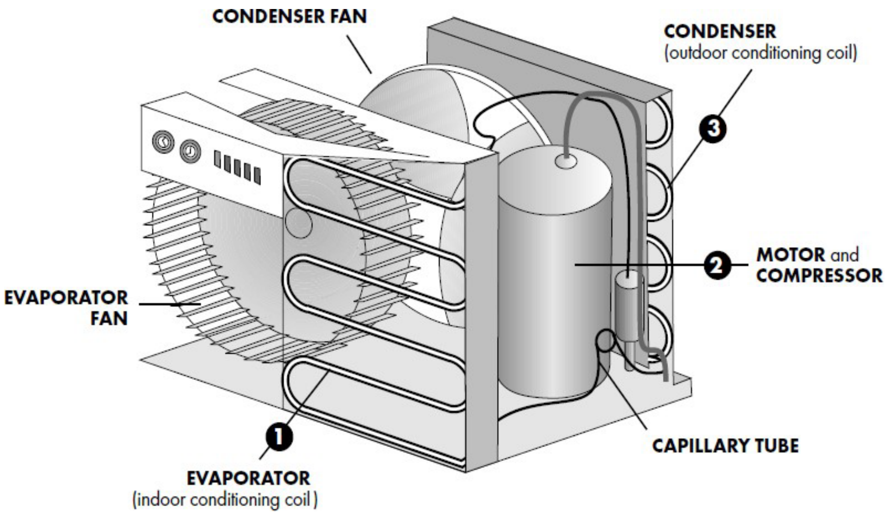

Figure 1. Schematic view of crack-inclusion problem

Fuzzy Logic Controller

The decision table is formed in the fuzzy logic controller to design a basic rule. This table includes input parameters and output parameters. The input parameters are the temperature of the user (Tu), Temperature Difference (Td), Number of occupant (Noc), time of the day (Tod), dew point temperature (Dpt), and weather condition (WC), while the output parameters are speed of compressor (Soc) and mode of operation. These rules were based on the user's experience.

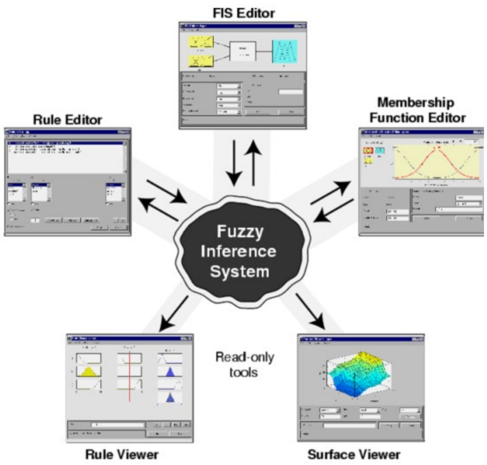

Figure 2. Fuzzy logic toolbox (Maldonado, 2014)

Fuzzy Base Class

Figure 3 shows the fuzzy base class of the work consisting of the input and output parameters.

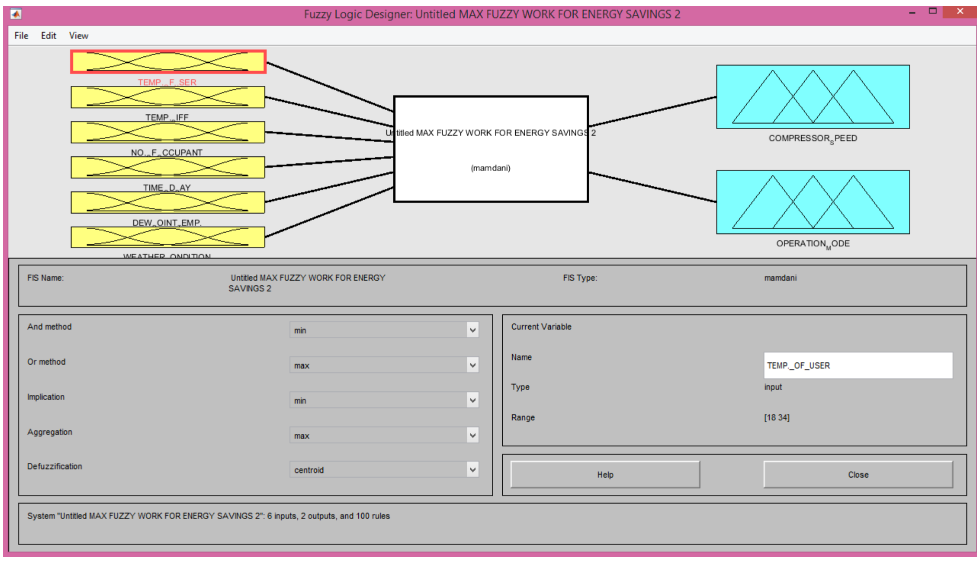

Figure 3. Fuzzy base class

Fuzzy Input and Output Variables and Fuzzy Rule

The input and output linguistic variables and terms are respectively defined in Table I and II. Status, as titled in the column in table I, presents user temperature (UT), Temperature Difference (Td), Number of Occupants (Noc), Time of the Day (Tod), Dew point Temperature (DPT), and Weather condition of different condition which accordingly represents various changes in the indoor environment. The unit is fixed based on studies by Shodiya et al. [8]. In this study, 100 rules are set accordingly to change the output parameters of different input parameter conditions, as shown in Figure 4.

Table 1. Input variable

Variables	Status	Unit (°C)
Temperature of User (Tu)	Low, Medium, High	15(°C) to 45(°C)
Temperature Difference (Td)	Negative, Zero, Positive, High Positive	-5 to 20
Number of Occupants (Noc)	Zero, Low, Medium, High	1 to 10
Time of Day (Tod)	Morning, Afternoon, Night	1:00 to 10:00 (morning), 11:00 to 17:00 (Afternoon), 8:00 to 24:00 (Night)
Dew Point Temperature (Dpt)	Optimal, Humid	
Weather Condition	Hamatan, Dry Season, Raining Season	1 to 2 (H_{Tan}), 3 to 4 (D_{season}), 5 to 10 (R_{season})

Table 2. Output variable

Variables	Status	Unit (%)
Compressor Speed (Soc)	Off, Low, Medium, Fast	30 to 100
Mode of Operation	Air Conditioner, Dehumidifier	

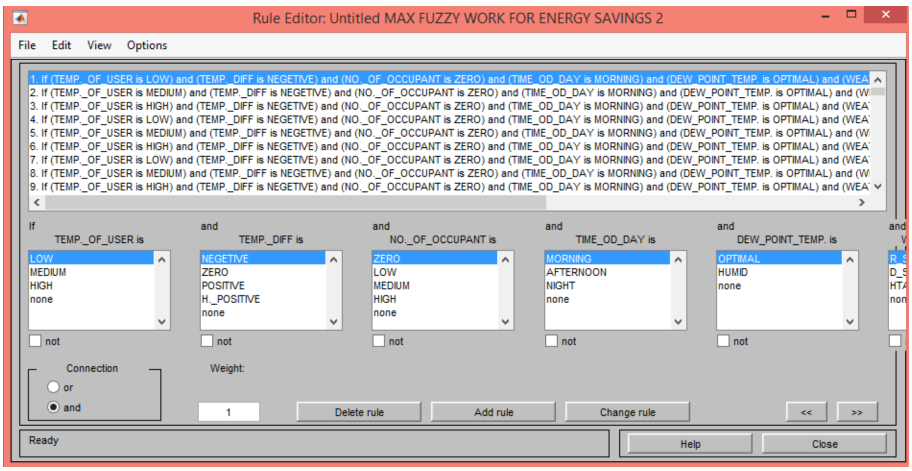

Figure 4. Fuzzy base rules

RESULTS AND DISCUSSION

Simulated Results

Various input variables and corresponding output variables were generated using fuzzy logic toolbox in Matlab. This fuzzy logic toolbox consists of the FIS Editor, membership function editor, rule editor, rule viewer, and surface viewer.

FIS Editor

System high-level issues are handled where several input and output parameters are declared with specific names. The shape associated with each parameter of all the membership functions is used to be defined by the editor. In this work, we used the Gaussian Membership function as in the equation below [10].

$$MF_{Gaussion}\ (x; a, b) = e^{-\frac{1}{2}(\frac{x-a}{b})^2} \quad (1)$$

Figure. 5 to 12 represents the membership function of the various input and output variables.

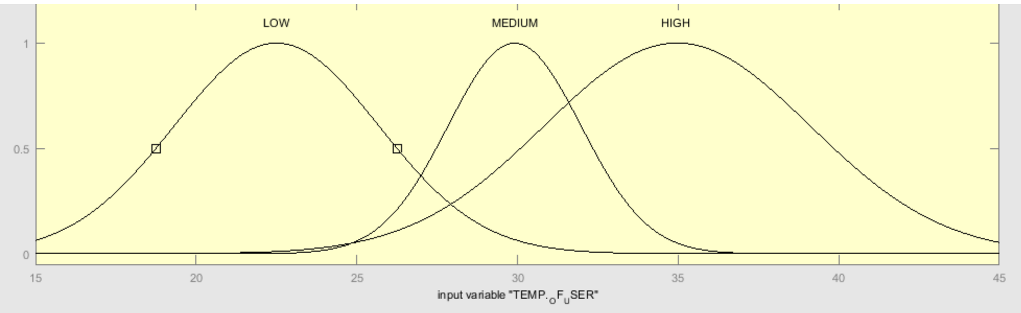

Figure 5. Temperature of user (TU) membership functions

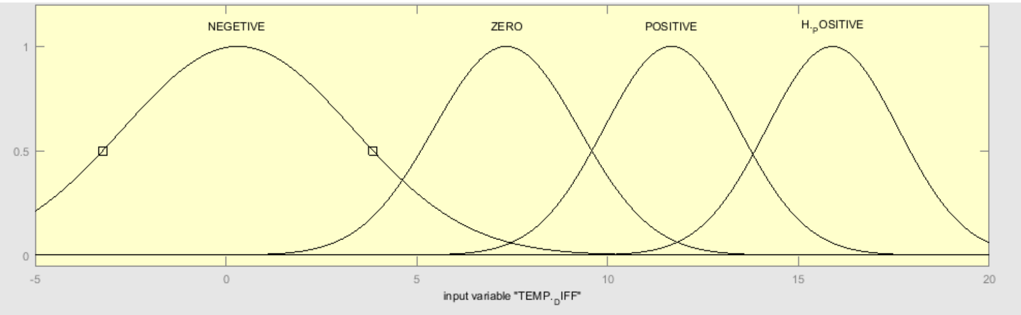

Figure 6. Temperature difference (TD) membership function

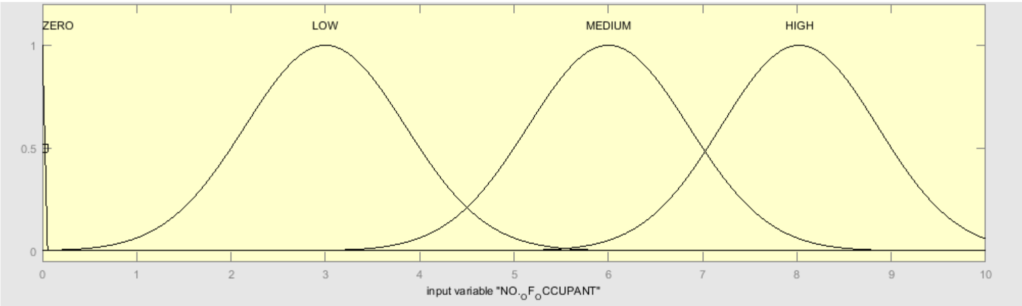

Figure 7. Number of occupant (NOC) membership functions

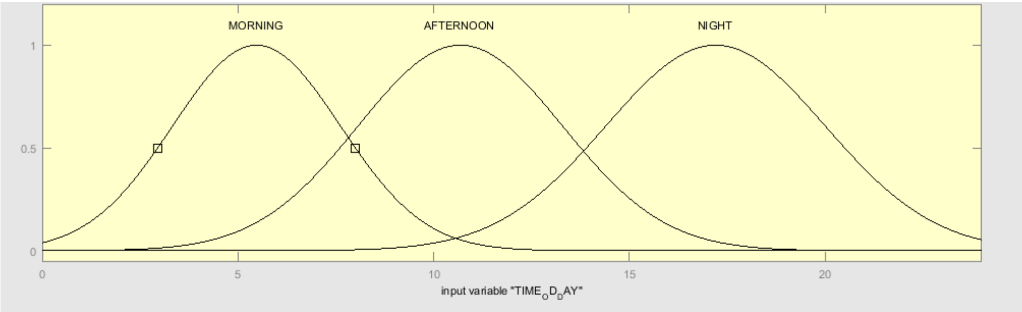

Figure 8. Time of day (TOD) membership functions

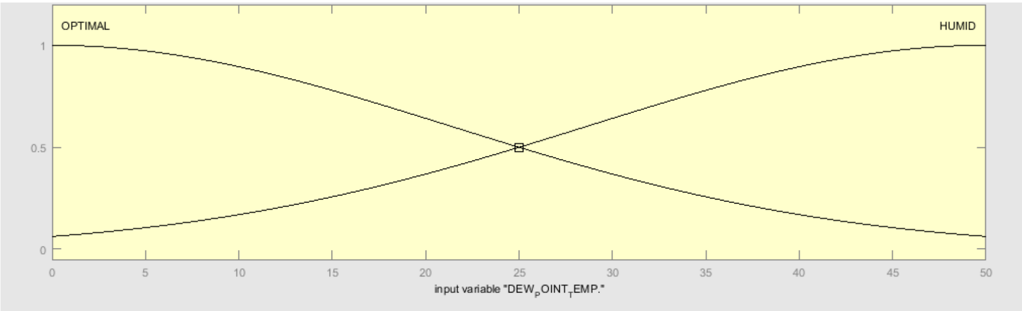

Figure 9. Dew point temperature (DPT) membership functions

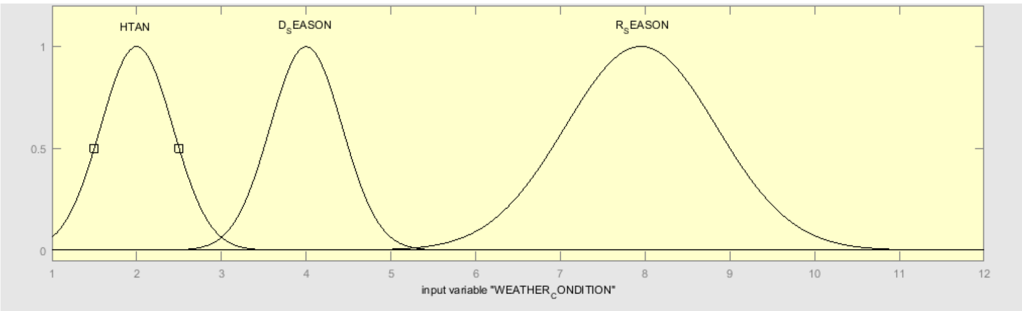

Figure 10. Weather condition (WC) membership functions

The fuzzy controller output parameters membership functions are:

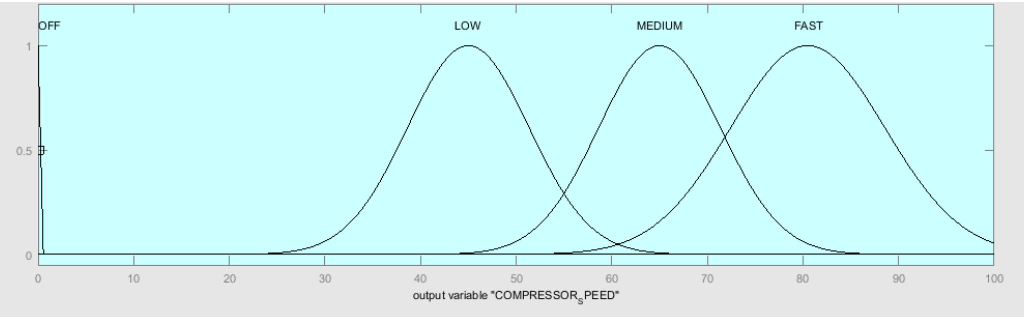

Figure 11. Speed of compressor (SOC) membership function

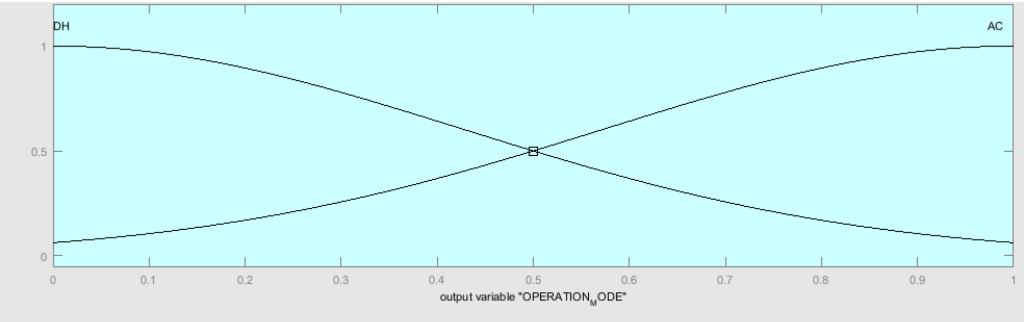

Figure 12. Schematic mode of operation (MOO) membership functions

Rule Viewer

To apply fuzzy logic design in this work to simulate input values of the fuzzy membership function, the rule viewer was used to give us ideas of the application, as shown in figure 13. This viewer is used to identify the system. It shows how active rules and the individual membership function relationship influence the result.

The following sets of input parameters were used, and the respective results were obtained as shown in the tables below.

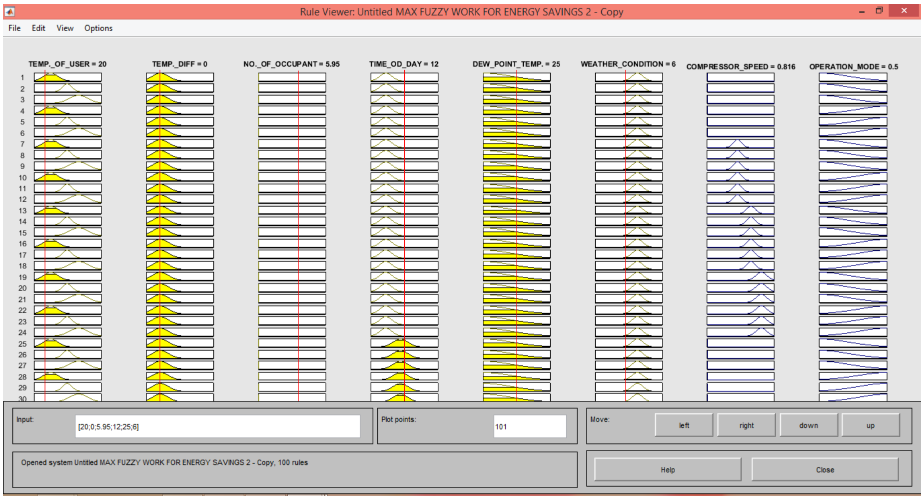

Figure 13. Fuzzy rule viewer

From the rule Viewer, as the Number of Occupants, User Temperature, and Time of the Day change the speed of compressor variation can be tabulated in table 3, table 4, and table 5 respectively.

Table 3. Speed of compressor variation as the number of occupants changes

INPUT VARIABLES					OUTPUT VARIABLES	
Temperature Difference	Number of Occupants	Time of the Day (Hours)	Dew Point Temperature	Weather Condition	Speed of Compressor (%)	Operation Mode
0	2	8:00	10	2	50	0.5
0	4	8:00	10	2	56	0.5
0	5	8:00	10	2	58.9	0.5

Table 4. Speed of compressor variation as user temperature changes

INPUT VARIABLES						OUTPUT VARIABLES	
User Temperature (°C)	Temperature Difference	Number of Occupants	Time of the Day (Hours)	Dew Point Temperature	Weather Condition	Speed of Compressor (%)	Operation Mode
15	0	5	8:00	10	2	56.1	0.5
18	0	5	8:00	10	2	58.2	0.5
27	0	5	8:00	10	2	58.9	0.5

Table 5. Speed of compressor variation as the time of the day changes

INPUT VARIABLES						OUTPUT VARIABLES	
User Temperature (°C)	Temperature Difference	Number of Occupants	Time of the Day (Hours)	Dew Point Temperature	Weather Condition	Speed of Compressor (%)	Operation Mode
26	0	5	3:00	10	2	16.3	0.5
26	0	5	4:00	10	2	39.7	0.5
26	0	5	12:00	10	2	58.9	0.5

Surface Viewer

Surface viewer Purposely displays the relationship between inputs and outputs Variables. Fuzzy controllers control the mode of operation. Room humidity condition is optimized with the help of the mode of operations. Air conditioning mode is switched on when the temperature is hot, making the room cool faster.

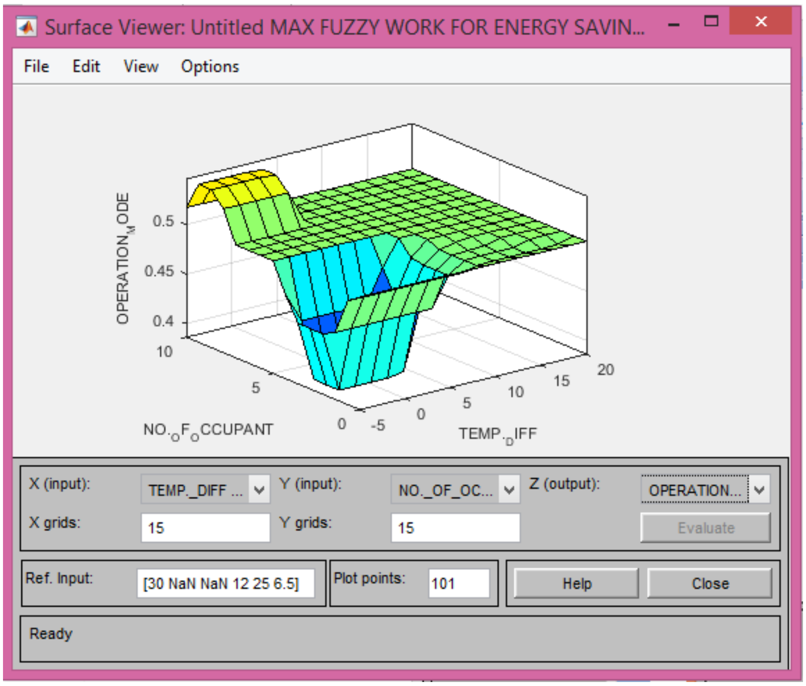

Figure 14. Surface viewer graph of temp. diff. vs no. of occupants vs operation mode

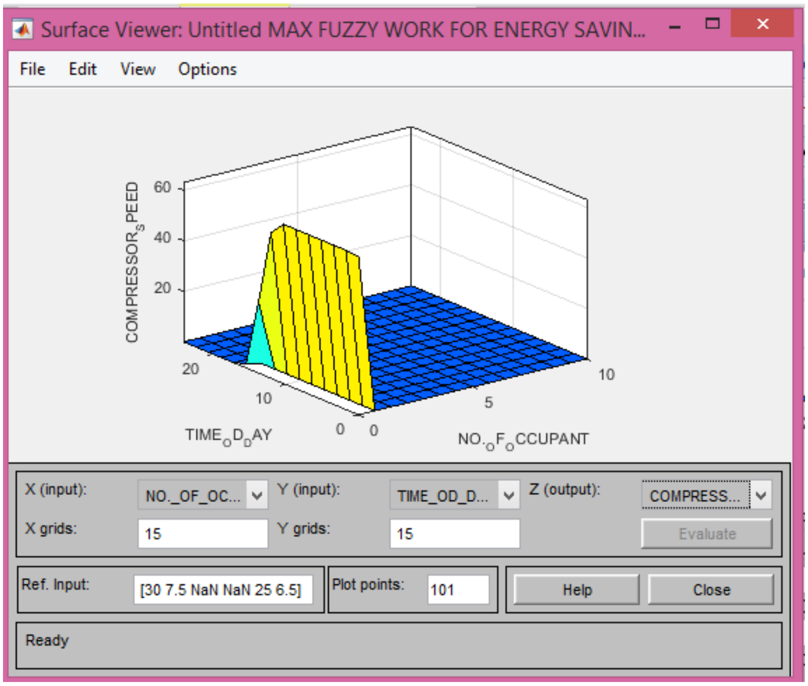

Figure 15. Viewer graph of no. of occupants vs time of day vs compressor speed

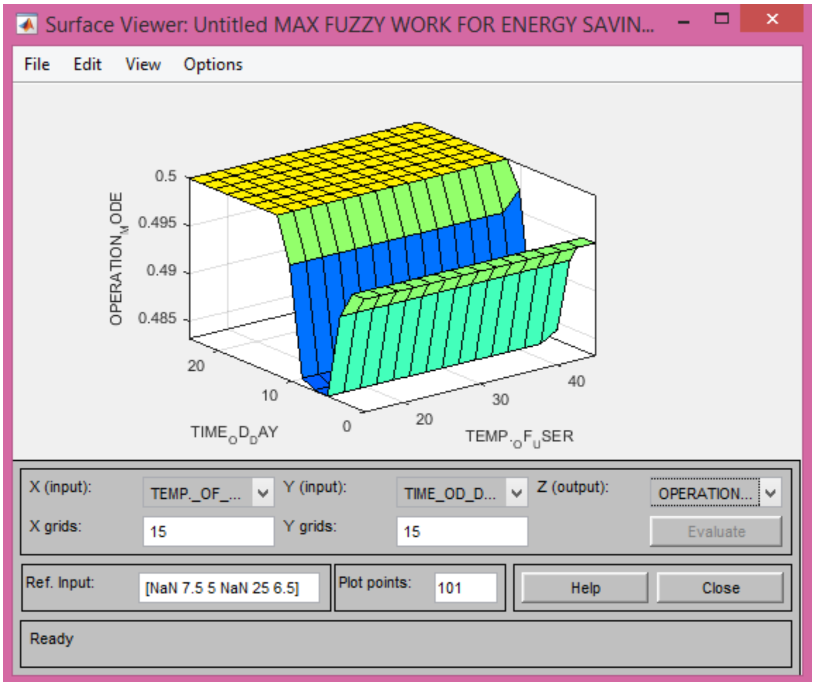

Figure 16. Schematic viewer graph of temp. of user vs time of day vs operation mode

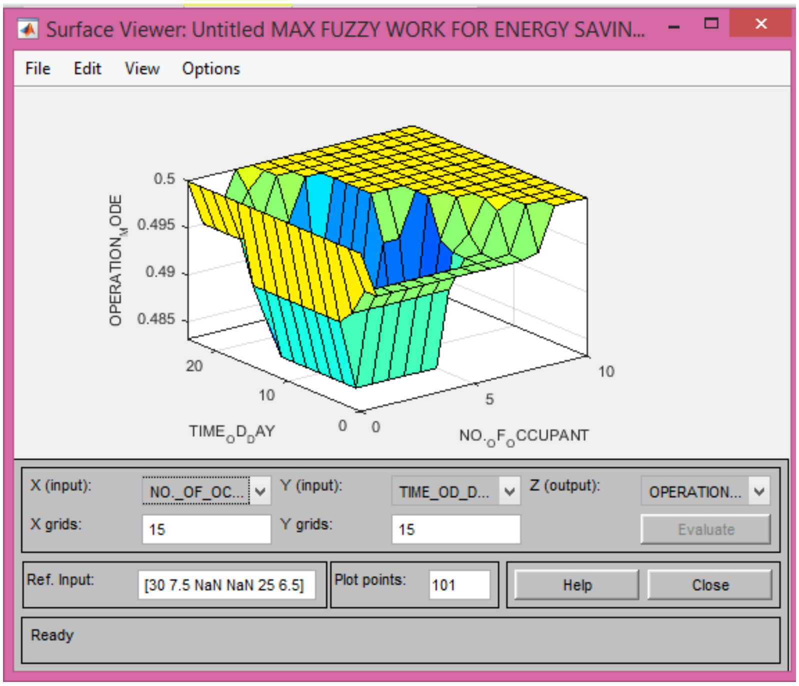

Figure 17. Schematic view graph of no. of occupants vs time of day vs operation mode

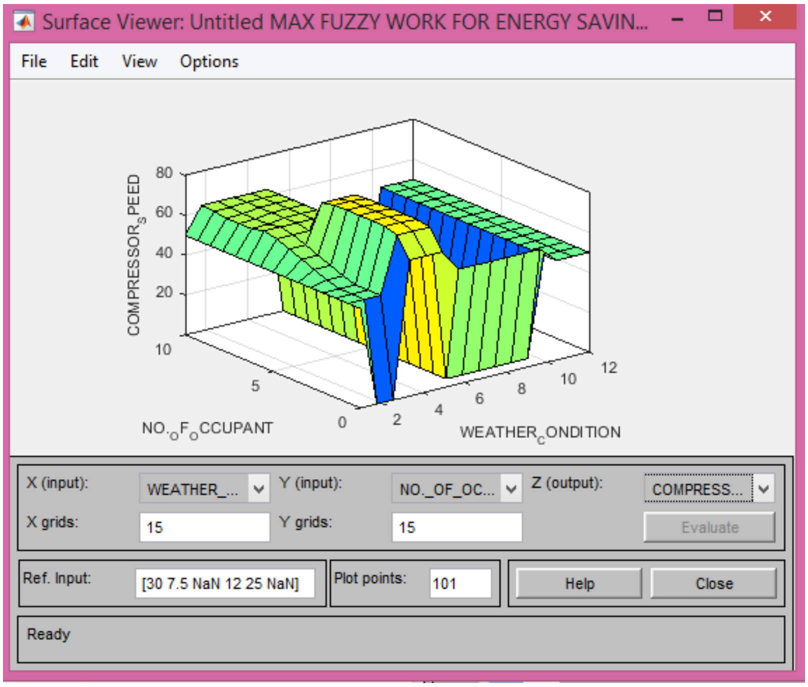

Figure 18. Viewer graph of weather condition vs no. of occupants vs compressor speed

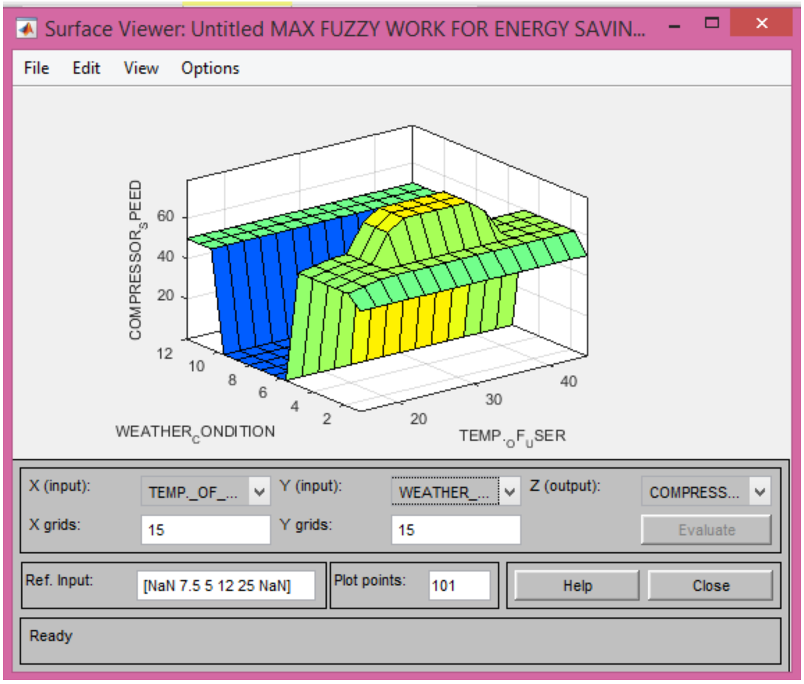

Figure 19. Schematic viewer graph of temp. of user vs weather condition vs compressor speed

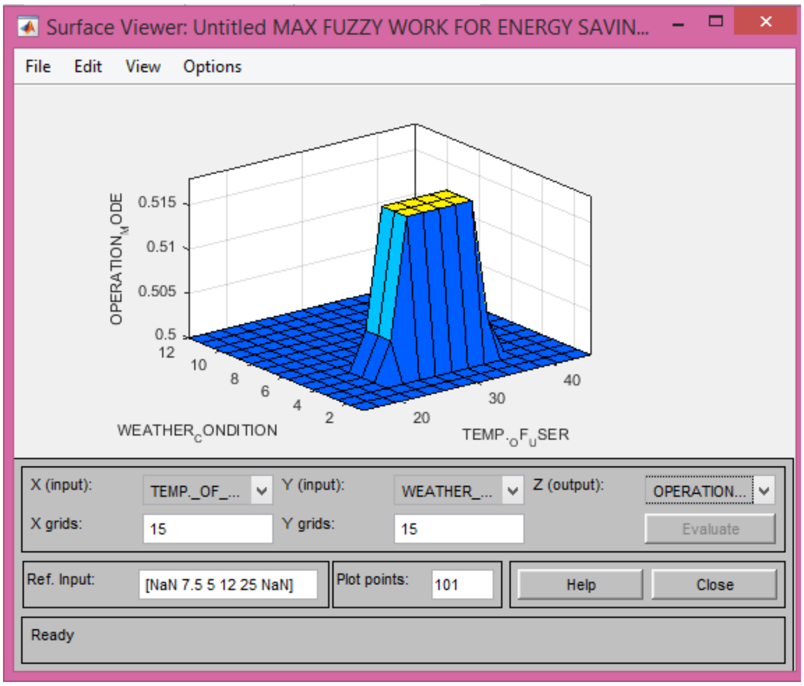

Figure 20. Schematic viewer graph temp. of user vs weather condition vs operation mode

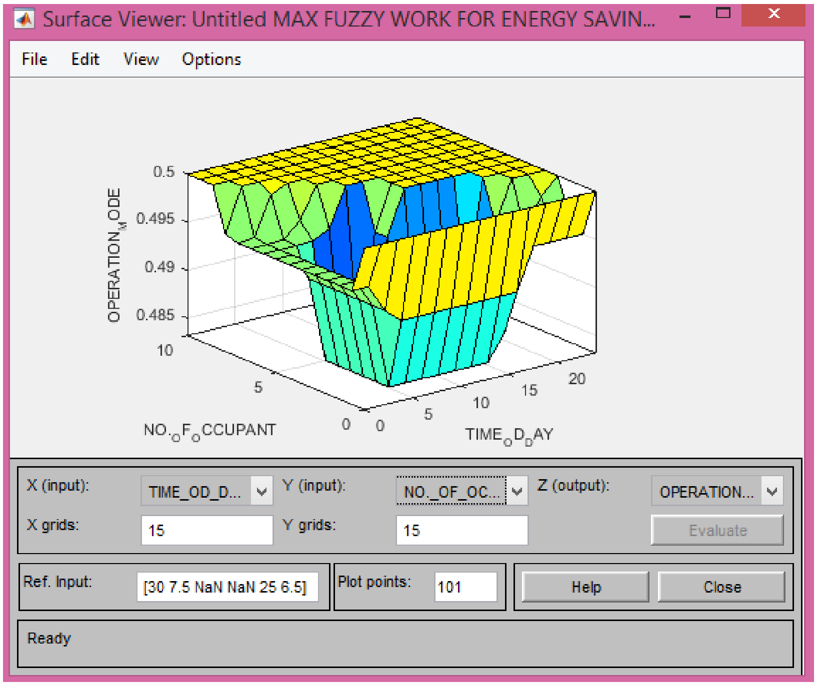

Figure 21. Schematic viewer graph of time-of-day vs no. of occupants vs operation mode

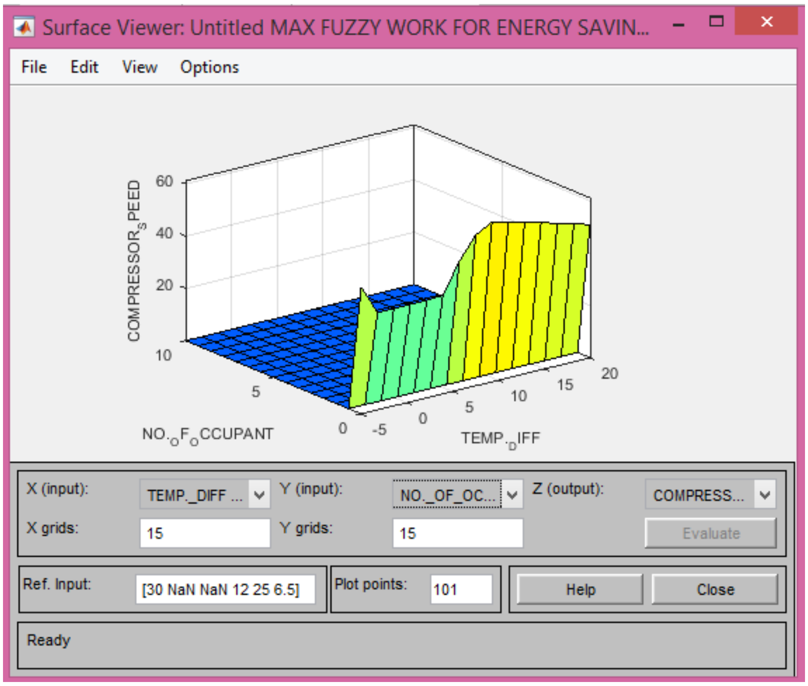

Figure 22. Schematic viewer graph of temp. diff. vs no. of occupants vs compressor speed

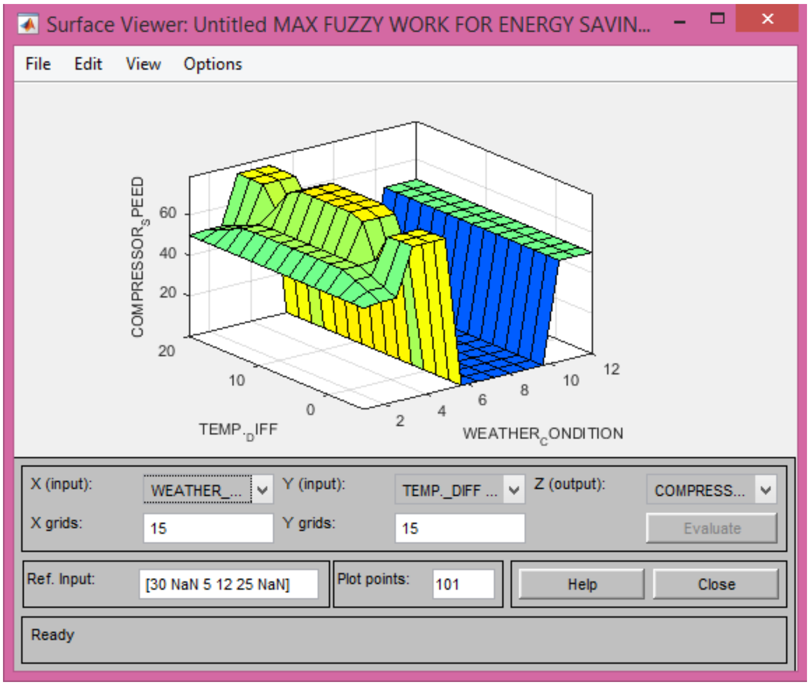

Figure 23. Schematic viewer graph of weather condition vs temp. of user vs compressor speed

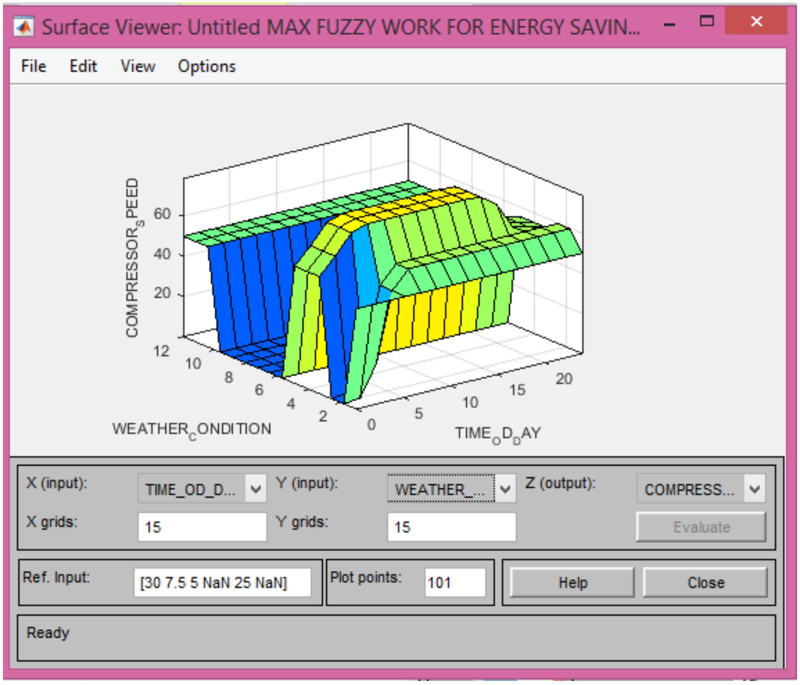

Figure 24. Schematic viewer graph of time of mood of the day vs weather condition vs compressor speed

CONCLUSION

The Fuzzy logic controller was designed to control the speed of the compressor to maintain a set point temperature of a room and to also control the mode of operation. Math lab Fuzzy Logic toolbox was used to simulate the controller performance. The indoor environment parameters are optimized by the controller as it has the capability of optimizing. The selected time of the day based on Morning, Afternoon, and Night results shows that early hours of the morning, 3:00 hours, 4:00 hours, and 6:00 hours the compressor speed dropped to 16.3%, 39.7%, and 58.1% respectively. This shows that the fuzzy design rule gives a satisfactory result in terms of energy savings, as 62% of energy can be saved when this fuzzy logic design is put into use.

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