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An Automated Fuzzy Logic Based Temperature Control Model for Sustaining Server Room Temperature Stability

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Abstract

The effect of unstable temperature in operating environment on server systems and other information technology equipment operational efficiency and durability is adverse. This research paper examines the complexity in sustaining server operating room temperature automatically without human intervention, irrespective of the changing environmental temperature that depends on climate. Due to in-depth literature review, a fuzzy logic based automated temperature control system that ensures the sustenance of server operating room temperature and enhances the durability of information technology equipments was designed and implemented. The system consists of an Atmel328 microcontroller, DHT11 humidity and temperature sensor, a five keypad, and standard relay for air-condition system interface. The data collected and analysed during the system implementation shows the system efficiency in controlling and sustaining operating environment temperature for server system, as well as work stations and power bank room. The proposed system operation is primarily concerned with specifying the desired operating temperature range.

Key words: Microcontroller, fuzzy logic, fuzzy controller, Temperature control System, Server room, Operating environment.

1.0 Introduction

The cost associated with setting up information technology infrastructure, maintenance and operation, such as server room, remains undoubtedly high. Hence, prompting the emergence of cloud computing infrastructure as a service sector. Although the emergence of cloud computing infrastructure as a service removed the burden of infrastructure setup cost and maintenance/upgrade of failed hardware/software, the issues surrounding hardware failure still persisted. There are many factors accountable for hardware failure and one of the most commonis instability of temperature of the operating environment. Although hardware firmware can also be responsible but the vast majority are results of chip bursts and electronic components burst due to unsteadiness of operating temperature.

Information technology equipment such as server's processors contains components that conduct electricity which is dissipated in the form of heat while in operation. This heat further affects their overall operating capacity, due to the expansion and contraction they undergo during temperature fluctuation of the operating environment. Although, air conditioning systems has proven to be a common resort for regulating temperature of servers operating environment, it lacks the capability to monitor and sustain a fixed temperature as a result of the impairment from outside environment temperature. Furthermore, the cost associated with manual control of an air-condition system to ensure sustainability of server operating environment temperature in terms of energy efficiency and manpower is marred with inaccuracy and inefficiency. Therefore, the task of ensuring the durability of servers goes beyond providing air conditioning system but requires an automatic intelligent temperature system that monitors and regulates server operating temperature. In response to this problem, numerous researchers have developed temperature control systems with respect to energy efficiency, cost and durability.

Thus, this paper delves into the design of a fuzzy based automated server operating environment temperature control with the capability to sustain the durability of other information technology equipments.

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2.0 Related Work

In [1], a smart automated fan controllerfor enhancing temperature control at the comfort of users was developed. Unfortunately, it was based on conventional control strategythat it was improved in [2]. Furthermore, in order to resolve a temperature control problem,many advance techniques such as artificial neural network has been employed [3]. Thus, in continuation of temperature control using smart fan as an economic alternative for cooling, a fuzzy based fan speed control system was developed in [4]. Their design employed a more efficient technique for temperature control. In addition, a vehicle cabintemperature control system based on fuzzy logic using temperature and humidity as parameters was then developed in [5]. Their model was more generic, making it suitable for any vehicle cabin.Another temperature control system based on fuzzy logic was designed in[6].While most research literature are centre on temperature control due to the importance of sustaining a fixed temperature,a fuzzy based temperature control and sustenance modelthat sustains a fixed temperature was designed in [7] and was successfully implemented on an embedded system, consisting of a 4*4 keypad for input of fixed temperature, and LM39 temperature controller.This model allows the heating up to any level and sustains the temperature at any specified fixed level, but,requires provision of proper operating environment temperature and sustainability to prevent expansion and contraction of its electronic components, which mostly leads to failure.

3.0 Automated Fuzzy Logic Temperature Control Model (AFLTCM)

Theproposed AFLTCM fuzzy model takes input data from DHT11 temperature and humidity sensor. These data are then acted upon by the fuzzyfication scheme of fuzzy model to map these data into a fuzzy linguistics that can be processed by the fuzzy rule based for further decision inference. The decision inference will further be defuzzyfied into a value suitable for controlling the airconditions in the server room.

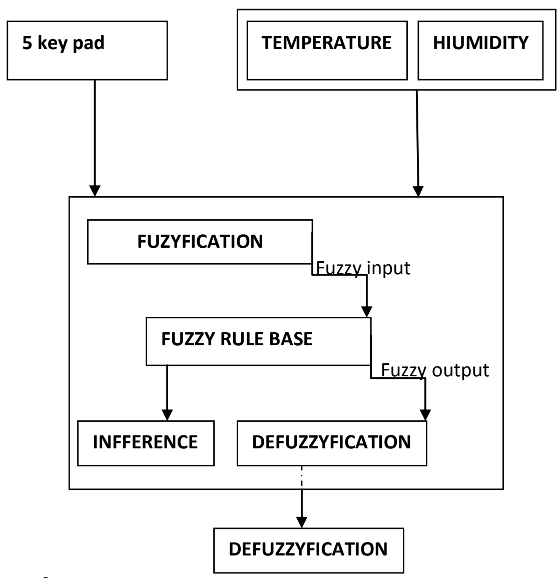

Figure 1: AFLTCM Software Architecture

AFLTCM Fuzzification considers the vast range of operating temperature requirements for server operating environment from varying manufacturers which ranges from 10 ^{o}C to 29 ^{o}C. In addition to the complexity involved in temperature control and sustainability in server rooms, AFLTCM fuzzy set linguistic for fuzzyfication of sensor input is defined as:

Let X = (B, S1, S2, S3, S4, R, AS, AR) (1)

Where, each Xi corresponds to a range of temperature shown in Table1. Also four specified temperature ranges, to reduce the length between manufacturers specified operating temperature was also introduced as depicted in Table1.

Table1: AFLTCM range of temperature from varying manufacturers

Temperature	Fuzzyfied input
<=9°C	Below specified(B)
10 °C1 - 13°C	specified range1(S1)
14 °C - 17 °C	specified range2(S2)
18 °C - 21 °C	specified range3(S3)
22 °C -25 °C	specified range4(S4)
26 °C -29 °C	Recommended (R)
>=30 °C	above specified range(AS)
>=38 °C	above recommended(AR)

AFLTCM FUZZY RULE BASED depends on the server system manufacturesoperating environment temperature specification, and the chosen specified range by data centre operator/designer, thefuzzy rule base determines the state of the cooling system. Hence AFLTCM fuzzy rule is defined as a set Y, Where

Y={HIGH,LOW} (2)

Table2: AFLTCM fuzzy rule

FUZZYFIED INPUTINSIDE	
IF TEMPERATURE IS Below specified	LOW
IF TEMPERATURE IS equal specified range1	LOW
IF TEMPERATURE IS equal specified range2	LOW
IF TEMPERATURE IS equal specified range3	LOW
IF TEMPERATURE IS equal specified range4	LOW
IF TEMPERATURE IS equal Recommended	LOW
IF TEMPERATURE IS above specified range	HIGH
IF TEMPERATURE IS equal above recommended	HIGH

Following the fuzzy rule in eq.2, we define AFLTCM fuzzy set membership set as follows

U={x<0<z} (3)

Where x is the set of all negative integers, z is the set of all positive integers

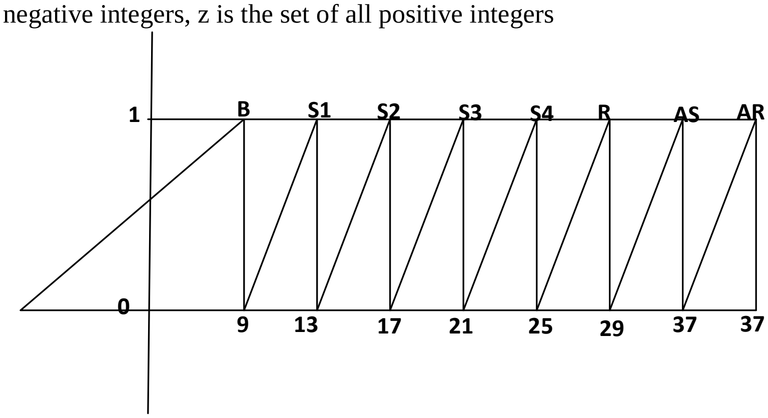

Figure 2: AFLTCM fuzzy set membership

3.1 AFLTCM Fuzzy Inference Model

The Inference model of our fuzzy controller consist of a set of corresponding action/decision to be taken based on the fuzzy rule as defined in Table2. For example, if the chosen specified operating environment temperature is range1, then for that server room, the cooling system will be LOW when the temperatureis within the range1, HIGH when above range1, and LOW when below range1. Similarly, when any of the sub-group specified servers' operating environment temperature is chosen by the data centre operator/designer, varying inference is implemented as shown in Table3.

Table3: Chosen specified server operating environment temperature sub

Chosen specified server operating environment temperature sub	INPUT TEMPERATURE		
	<	>	==
specified range1(S1)	LOW	HIGH	LOW
specified range2(S2)	LOW	HIGH	LOW
specified range3(S3)	LOW	HIGH	LOW
specified range4(S4)	LOW	HIGH	LOW

3.2 AFLTCSMHardware Architecture

The fuzzy model implementation as depicted by Figure 3 is an integration of hardware and software converging into an embedded system solution.

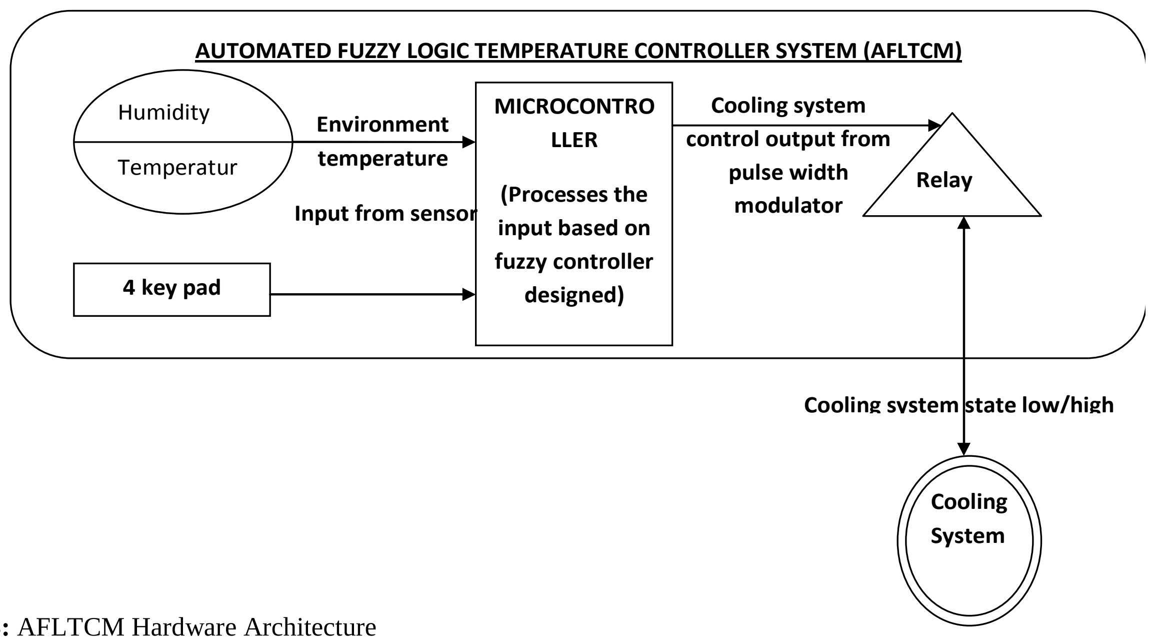

Figure 3: AFLTCM Hardware Architecture

3.3 AFLTCM Components

Figure3 shows that the system consists of four major components, an Atmel328 microcontroller, an integrated humidity, a 5key pad and a temperature sensor module commonly referred to as DHT11 and a relay driver module. Each component plays a special role in the overall system operation. While being connected to and controlled by the microcontroller that acts as the system processor.

The choice of 16bit atmel328 microcontroller for system development was influenced by its ease of interfacing, cost effectiveness and processing efficiency. The main role of the microcontroller in AFLTCM system includes receiving key pad input as data, processing these inputsto determine the current server operating environment temperature, and further implements a reduction on the current flow to the relay, which directlychanges the operating speed of the cooling system.

The function of the sensor unit is to serve as input device to the system as a whole and primarily to the embedded microcontroller. Due to the energy efficiency and cost effectiveness of this DHT11 sensor module, it became the choice component for AFLTCM.

Relay driver module is necessary to bridge the control system and cooling system.
The keypad gives operation scalability to data centre operators/designers as they have the choice of reducing the movement within a small fixed range group of operating temperature that improves the durability of server system.
The cooling systemis an air condition system that is left to run at a fixed temperature, irrespective of the outer environment temperature. This is undoubted energy inefficient and highly expensive solution for server room temperature control.

4.0 Results of Finding

The system implementation was carried out using the Delta State University electronic centre server room. During which, the server room, power bank room and personal computer room operating temperature was monitored and controlled to ascertain the efficiency of our temperature controller

4.1 Server Room

TheFigure 4 displays the analysis of the data logged from the temperature sensor during the test run of recommended temperature (R).The temperature data are represented by the red lines while humidity data, although not considered as input to the system, is indicated by the blue lines.
Clearly, it can be inferred that the controller consistency in ensuring the operating temperature range R was maintained throughout the test, despite the increase in the number of persons entering the server room and the effect of the door opening and closing irregularly. This test on operating environment condition is only favourable to server systems if the current environmental temperature range is sustained with the AFLTCM small fixed range, which will not lead to early damage of the systems.
From the Figure4 chart, the server room temperature value was consistently at 28^0C and the relative humidity at 0.77%. This temperature, although within the recommended range, isfavourable to the durability of serversystems because of the fuzzy component, considering the losses and cost incurred when the electronics fail.

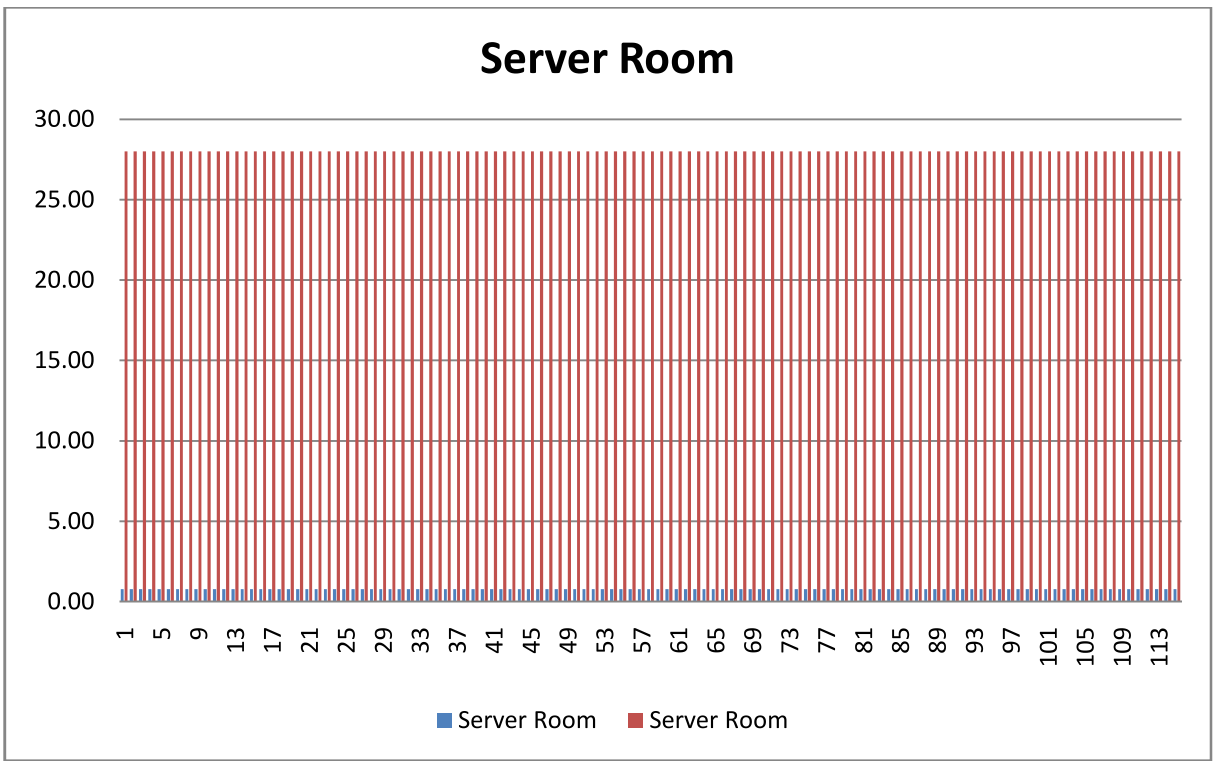

Figure 4: Chart of the relative humidity with temperature of server room operating environment of delta state university electronic centre

Power bank roomis a vital component in server operation because it is a durability enhancer through prevention of irregular server shutdown resulting from power outage. The operating temperature of the power bank room of the Delta State University electronic centre was considered during implementation. Data collected as depicted in Figure 5 indicates fluctuation in operating environment temperature and this validates our system temperature controlling capability as it falls within the range of pre-specified operating temperature range in accordance with the fuzzy controller. Similarly the Figure5 chart indicatesthe consistencyvalue of the power bank room temperature between 28^0C at relative humidity of 0.76%, 0.78% and 29^0C at relative humidity of 0.76%, 0.74% respectively.

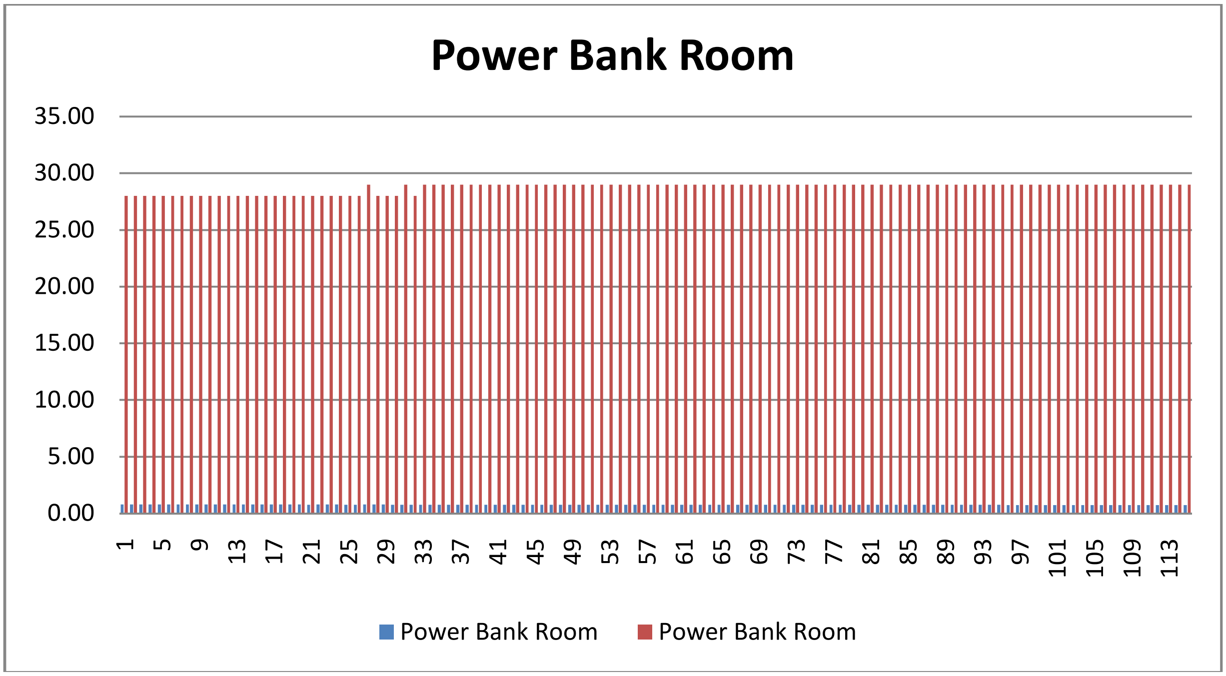

Figure 5: Chart of the relative humidity with temperature of power bank room operating environment of delta state university electronic centre

Personal computer (PC) hall: Although temperature control for personal computers and workstations are not strictly enforced.It is necessary for a corporate organisation that is investing into information technology infrastructure to harness the full potential of our proposed model for durable operation. Also, server without client is of no use. This prompted the test operation on personal computer operating environment temperature control. During the test experiment, the operating environment temperature of personal computer hall was first monitored.Then, the cooling system was interfaced with our controller. From the Figure 6 chart, the server room temperature value was consistently at 28^0C and the relative humidity at 0.77%. This temperature is sustained within the recommended range and so favourable to electronics durability.

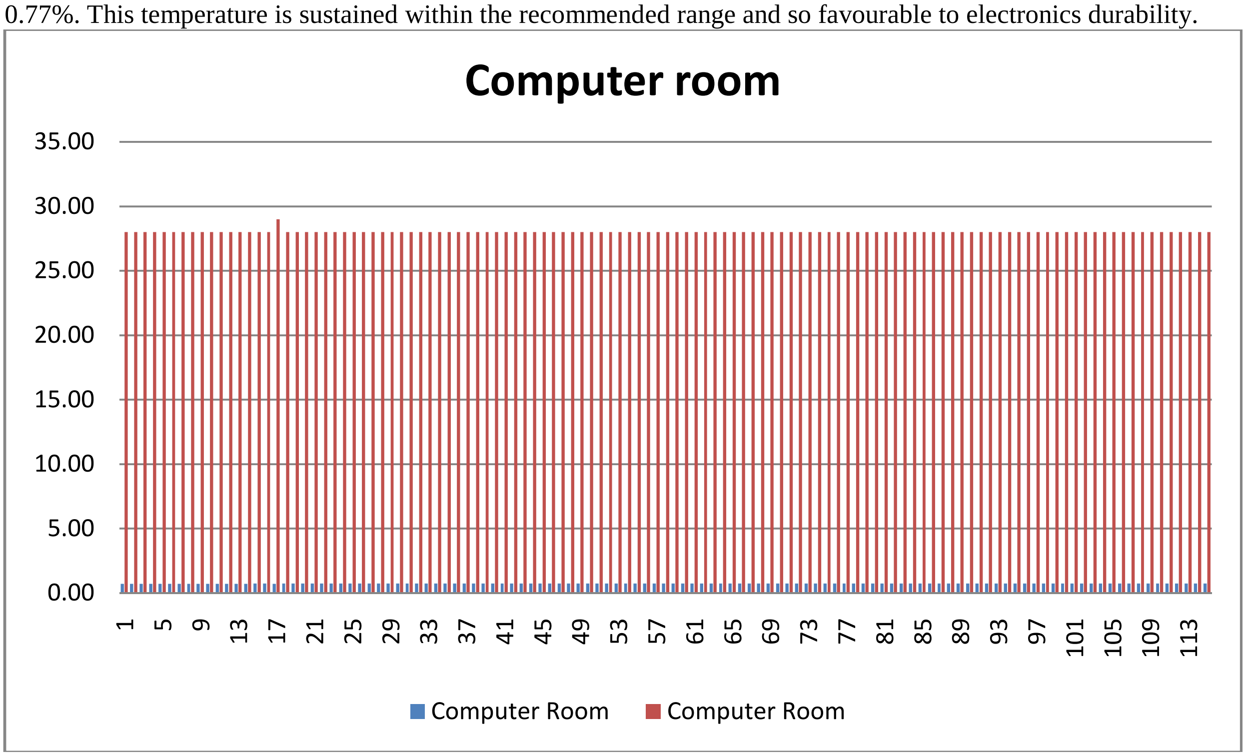

Figure 6: Chart of the relative humidity with temperature of computer hall of Delta State University digital centre

5.0 Discussion

The development of a temperature control system is a broadly based effort to achieve appropriate control of the temperature in a server room irrespective of the weather. This research workshowed the impact of temperature control system on servers and the necessary solution towards preventing threat to servers. In this proposed system, less or no error are gotten due to thefact that instructions are written for execution in the IDE of the microcontrollers that is used in decision making. Development of a temperature control system provides the means of reducing the intervention of network administrators towards constant monitoring of the temperature in the server room.

In other words, after server room operating environment of the temperature test run, the graph showed that the temperature was sustained at s4 specified temperature range. Hence, fulfilling theAFLTCM overall objective, by sustaining the temperature, That notwithstanding, the use of either S1, S2 or S3 specified temperature ranges is recommended for better cooling that guarantees proper functioning of electronic components and overall server computer system durability.

6.0 Conclusion

Ensuring the efficiency and durability of servers is of vital importance since servers continue to play a crucial role in information technology. To combat this issue, a temperature control system was developed using fuzzy logic to eliminate the complication in temperature control task which is a non-linear task. In an effort to implement the AFLTCM, Delta State University (DelSU) electroniccentre server room, power bank room, and personal computer hall/room was used because the existing system in DelSU is operating at although specified temperature range,but is not favourable to the durability of the electronic systems. Hence, the use of either S4/S3/S2/S1 is recommended. In addition, the result of AFLTCM implementation indicates effectiveness of the proposed system capability to ensure the sustainability of fixed range of operating environment temperature as evident in the power bank room, server room and PC hall. The three rooms showeda temperature within 28 to 29 consistently. The use of fuzzy logic greatly enhance the effectiveness of the temperature controller and the durability of server system, through elimination of the complexities involved in temperature control, and re-categorizing the manufacturers specified operating environment temperature requirements for servers and equipment, due to the large inconsistencies between the minimum and maximum, which is unfavourable to electronic components. This system promises to improve the overall durability of servers and information technology infrastructure through sustaining the environment temperature. Further analysis on S3, S2 and S1would be carried out to attain if the proposed model is fully robust.

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