Effect of Temperature Compensator in Thermal Efficiency Management in Data Centre

C.T. Ikwuazom[1], D.O. Njoku[2], E.C. Nwokorie[2], I. A. Amaefule[3],
O.C. Nwokonkwo[4], J.E. Jibiri[4],T.C. Okeahialam[1] F.U. Madu[5]

[1]*Department of Information Media Technology, Federal University of Technology, Minna, Niger State*
[2] *Department of Computer Science, Federal University of Technology, Owerri, Imo State*
[3] *Department of Computer Science, Imo State University, Owerri*
[4] *Department of Information Technology, Federal University of Technology, Owerri, Imo State*
[5]*Department of Computer Science, Federal Polytechnic, Nekede, Owerri*

Abstract: This paper has examined the effect of temperature compensator in thermal efficiency management in data centre. The use of computer room air control (CRAC) unit in ensuring thermal efficiency facilitate thermal process stability such that variation of temperature does not exceed predetermined value expected for effective working of data centre infrastructures such as computer hardware and server racks. A proportional-integral-derivative (PID) tuned compensator was designed in MATLAB environment and introduced into feedback network of thermal process in a data centre. Simulation result showed that predetermined temperature of 1°C was maintained when the designed compensator was introduced. Hence, the compensator provided thermal efficiency and stability by ensuring that the expected temperature in the data centre was not exceed and no deviation in the ideal temperature of the computer room air temperature (CRAT) and actual value obtained as step response.

Keyword: CRAC, Compensator, Data centre, Efficiency, Thermal process

1. Introduction

The use of electronic equipment in homes, offices and other enclosed spaces has rapidly increased in recent times. One of the most widely used electronics is computer and it is important electronic equipment in indoor environment whose use has dramatically increased over the past few decades. Computers are penetrating every work place and home, and are used for a vast range of tasks including as data storage facilities in data centre.

In many organisations and institutions such as Information and Communication Technology (ICT) companies and school computer laboratories/classrooms, a number of computers are introduced in offices and other indoor environments to facilitate data processing, storage, sharing of information, file management, and learning. The use of computers as essential electronic component of ICT is changing the way businesses are conducted by organisations including educational institutions. These changes have impacted on data/information sharing or storage practices among institutions globally.

Also, the demand for data processing is on the rise in recent times because of the technological advancements in computer and electronic systems, which has caused a rapid increase in data centre sector[1]. The advances in Information and Communication Technology (ICT) devices have invariably resulted in huge data that must be processed and kept in data centre. In fact, data centre is a key component of ICT that is used in the collection, storage, processing, and distribution of big amount of data for application such as business enterprise, cyber-physical system, and social networking. Hence, data centre workload and its energy consumption are rapidly increasing due to the continuous rising demand of remote data services [11].

With data centre rapidly becoming a critical asset for companies because valuable and sensitive data that are essential to the sustainability of business activities are stored in it, there is need to ensure that the computers in data centres are operationally reliable. One of the environment factors that can adversely affect the safety and reliability of the data centre is the thermal energy within the computer room. Thermal energy in a data centre can be described as a measure of air volume temperature of the room. Thus, temperature profile is critical to energy efficiency and effective working of a data centre. This is because computers and network devices in data centre are susceptible to high temperature. In some countries, standard temperature in data centre or server room is established. For instance, in Indonesia, the standard temperature for server room is 21 – 23°C [9]. The allowable temperature range given by American Society of Heating, refrigerating, and Air-Conditioning Engineers standard is 18 – 27°C [3]. Hence, regulating temperature in data centre and achieving optimal uptime and efficiency is critical [8].

Several techniques have been implemented to facilitate computer room air temperature control that ensures that temperature in a data centre is kept at predetermined value or range. In this paper, the objective is to study the effect of temperature on the effectiveness and efficiency of data centre and how the implementation of temperature monitoring and regulating algorithm helps in ensuring that desired or predetermined temperature are maintained irrespective of disturbance caused by ingress of external hot air.

2. CRAC in Data Centre Architecture

The importance of data centre makes IT companies and other businesses that heavily depend on technologies to invest huge amount of money on top-quality equipment [5]. Nevertheless, high level of thermal energy is generated by these equipment that can be harmful to the operation of the in data centre in various ways. Thus, the effect of temperature in the efficient performance of data centre is considered in this section. A typical data centre structure is shown in Figure 1, and mainly comprising Information Technology (IT) system and computer room air conditioner (CRAC).

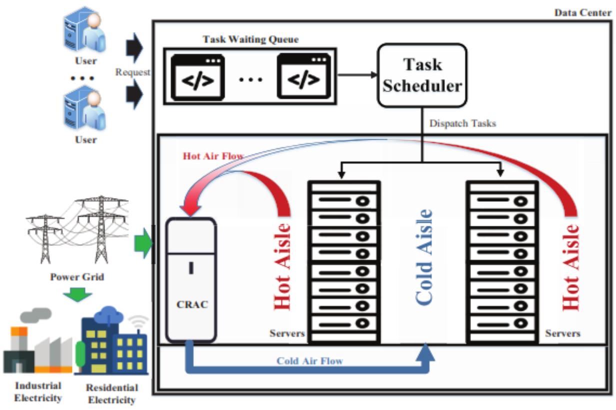

Figure 1: Data Centre Structure[2]

The purpose of CRAC in data centre is basically to ensure that a suitable environmental condition needed for the operation of IT equipment is created and maintained. That is the CRAC is the technology for controlling and maintaining optimal temperature, distribution and air flow within data centre. The CRAC technology ensures that heat conditions are regulated to provide the desired temperature for effective operation of data centre when the room is exposed to high-level temperatures as a result of the computer hardware capacity in data centres and network areas (Data Centre Cooling Explained). This way, the breakdown and permanent damage to hardware because of overheating that can be experienced from time is prevented. Generally, the operation of CRAC in data center is to guarantee precise humidity and stability of temperature suitable for high loading areas such as data centres, network areas and server rooms (XXXX).

In the absence of CRAC in data centre, mainframes and racks of servers can become overheated with time. The heat rejection of an average rack is 3 kW but there are servers with up to 20 kW of heat rejection, which makes sizing of the CRAC critical for regulating the temperature of computer hardware in making sure it runs smoothly.
Recently, several techniques have been developed to regulate temperature in data centres to improve the performance of CRAC. Some of the techniques involve the use of classical concepts such as proportional and integral (PI) feedback control, and proportional-integral-derivative (PID) control algorithm. Also, intelligent control systems such as fuzzy logic controller (FLC), and adaptive self-tuning PID-type fuzzy have been proposed in literature.

3. System Design

3.1 Thermal Model of Data Centre

The mathematical description of thermal process in data-centre is presented in this section. The model is a second order inertial and net delay process representing the transfer function of open volume to air temperature of a data centre given by[4]:

$$T(s) = \frac{10}{(20s+1)(30s+1)} e^{-12s} \quad (1)$$

Equation (1) represents the mathematical model of thermal process in terms of temperature in a data centre with a time delay of 12 minutes or 0.2 second. The mathematical derivation and operation of the fan speed in variable air volume (VAV) that was employed to determine the air flux in the data-centre considered in this study is in available in [4]. The model is used in this paper to study the effect of temperature in data centre via computer simulation using the MATLAB tool. Feedback network of temperature regulating closed loop system subject to unit step input in a data centre is shown in Figures 2. T_{ref} and T_{act} are the desired (or reference) temperature and actual temperature of the system.

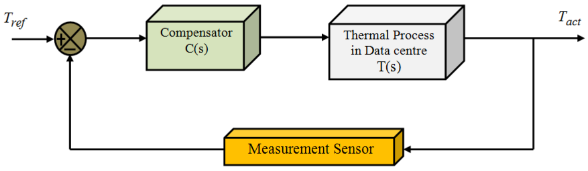

Figure 2: Feedback Network of Temperature Regulating Loop in Data Centre

3.2 Design of PID Tuned Compensator

The addition of compensator in feedback control system is an important technique that is commonly used in process industries [10]. The main advantage offers by compensated system is that corrective action takes place as soon as the actual output deviates from referenced input irrespective of the source and type of disturbance. Thus, compensators are sub-system that provides corrective action when introduced into system to compensate for performance deficiency of the plant or process[10].
PID tuned compensator has been proposed in [7] and [6] to achieved very impressive robust and desired input tracking performance. In this paper, a compensator is developed by employing PID tuning based on robust response time using Control and Estimation Tools Manager (CETM) of MATLAB computer simulation software. The tuning procedure is shown in Figure 3, which is single input single output (SISO) design tool graphical user interface (GUI). The PID tuned compensator incorporates first order derivative filter.

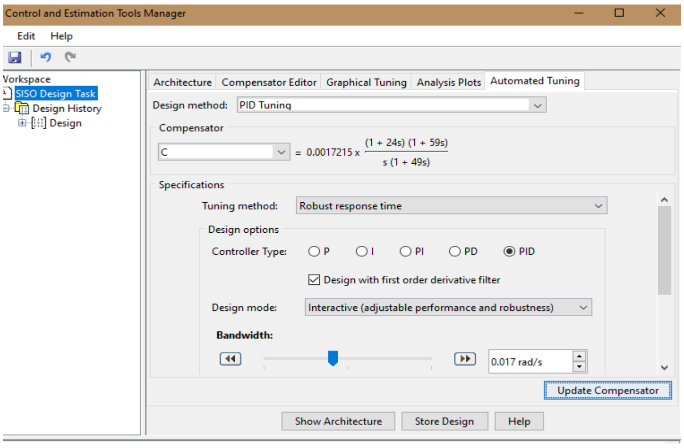

Figure 3 GUI of PID tuned compensator design

Thus from Fig. 3, the designed temperature PID tuned compensator for data centre is given by:

$$C(s) = 0.0017215\frac{(1+24s)(1+59s)}{s(1+49s)} \quad (2)$$

4. Simulation Result and Analysis

Using Equation (1) as a model of thermal process in data centre, the simulation of volume to air temperature was conducted in MATLAB R2015a environment and the system step response to unit step temperature input in degree is shown in Figure 4.

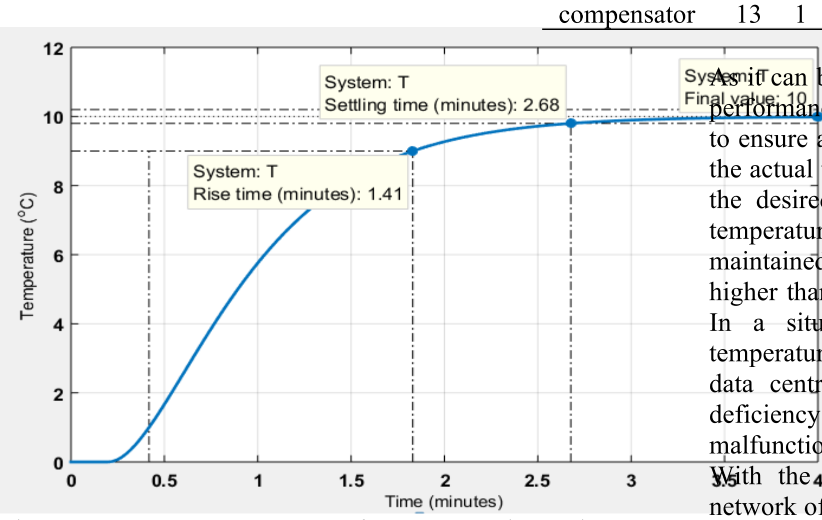

Figure 4 Temperature response of CRAC to unit step input (without compensator)

Further simulation was carried out to determine the step response of system to unit temperature input with the designed compensator introduced into the feedback network of the temperature regulator assuming the measurement (or temperature) sensor has a unit gain as shown in Figure 2. The result of the simulation is shown in Figure 5. The performance parameters of the system obtained in time domain from the simulation performed are given in Table 1.

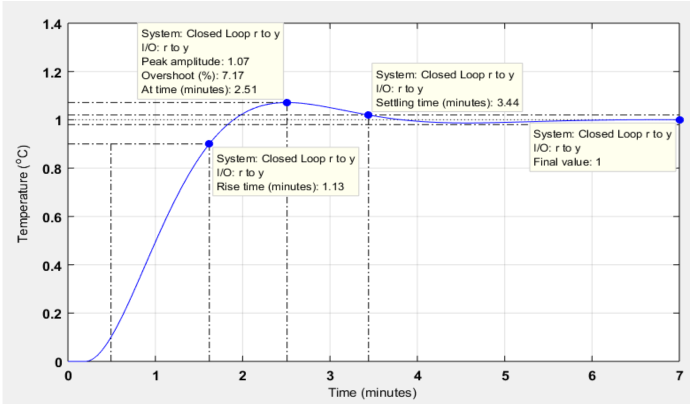

Figure 5 Temperature response of CRAC to unit step input (compensator)

Table 1: Time domain performance parameters of the system

System condition	Rise time (s)	Peak time (s)	Peak overshoot (%)	Settling time (s)	Final value to unit step input (°C)	Remark on step response performance to unit step input
System without PID tuned compensator	1.41	> 250	0	2.68	10	Unsatisfactory
System with compensator	1.13	2.51	7.17	3.44	1	Satisfactory

As it can be seen from Table 1, when the thermal process performance has not been compensated in the data centre to ensure a desired temperature is maintained in the room, the actual temperature in the room seems to be higher than the desired value. That is with expected (or set point) temperature in the room at 1°C, the actual temperature maintained in the room was 10°C, a value very much higher than the desired temperature as shown in Figure 4. In a situation like this in which desired level of temperature is not achieved but rather a higher value, the data centre can be overheated and thereby leading to deficiency in data centre operation and damage to or malfunctioning of IT infrastructures such as computers. With the introduction of compensator in the feedback network of the thermal process of data centre, which forms a CRAC, the desired temperature was achieved at the output as can be seen of the final value to unit step input in Table1, which shows that the system maintained steady and precise temperature corresponding to the temperature expected of data centre to operate smoothly. Thus as shown in Figure 5, with actual temperature (step response) value equal to desired value (unit step input), the deviation or error is zero and the as such a steady state temperature is maintained in the data centre. It suffices to say that the use of temperature regulating system in data centre will certainly improve system efficiency and stability.

5. Conclusion

The effect introducing temperature compensator in ensuring thermal process efficiency in data centre has been examined via computer simulation in MATLAB 2015a environment. The system performance was analyzed in terms of transient and steady state step response to unit step input temperature (expressed as 1°C). The results obtained from the computer simulation tests conducted showed that remarkable performance in terms effectiveness in maintaining an ideal predetermined temperature was achieved using a compensator in the feedback temperature control loop of thermal process in data centre.

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