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Research Article

Energy Performance Optimization of Server Room HVAC System

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Abstract

Server room containing computing equipment's such as server, network, and storage devices that compute, transport, and store information. The maximum energy consumption of server room is used for cooling purpose. Out of total energy consumption approximately 38% of the energy consumption is used for cooling. This paper aims that energy used for cooling system optimized by various methods. In this server room the method of raised floor & cold aisle, hot aisle arrangement of cooling is used. In this method cold air flows from bottom discharge of PAC machine which flows below false floor & comes to server racks. Thus the cold air is in contact with hot server rack and absorbs heat of rack. This paper seeks to present all necessary data required for efficient server room and provide better platform for improvement in air flow management. Thermal performance of server room directly related to airflow management. To achieve performances this paper discusses all necessary technique in details.

Keywords: *Server Room, Cold Aisle Containments, Hot Aisle, Air Flow, Cooling, Energy Consumption.*

1. Introduction

All of the electrical power drawn by the IT equipment in a server room is converted into heat energy, forcing server room to utilize a significant portion of their power consumption for cooling. In the worst cases, more than 38% of the server rooms total energy consumption is used for cooling the facility (EPA Report). Fig. (1) Shows a typical energy consumption breakdown of a server room. As heat dissipated by server rack is absorbs by cold air flowing from the floor grills. If this cold air is mixed with return hot air prone to create 'hot spots' in certain locations in the server room which force the server room managers to over-cool the facility [Taesub Lim *et al*].

Hence, to avoid this generation of hot spot in server room we required to use standard method of cooling in server room (cold aisle containment) and understand what improvement of energy consumption in server room [Jinkyun Cho *et al*]. Thus for checking energy consumption of server room following are the measures of energy efficiency widely recognized. In order to quantify the energy efficiency of server room, a number of different metrics are being used. Although many organizations have called for standardization, two competing metrics are in wide use: Data Center Infrastructure Efficiency (DCiE) and Power Usage Effectiveness (PUE) [Yiqun Pan *et al*].

*Corresponding author: **Manoj Jadhav; Pramod Chaudhari is working as Associate Professor**

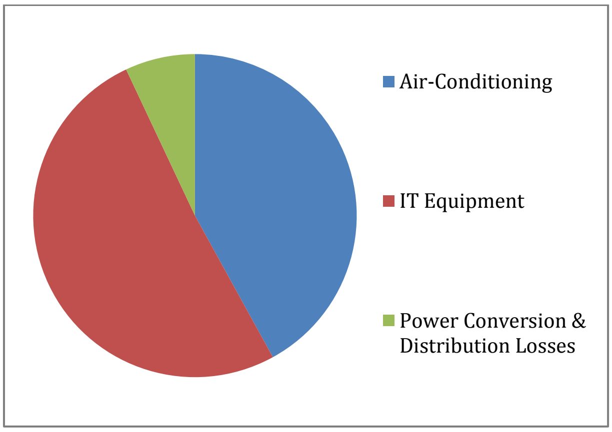


Fig 1: Energy consumption breakdown of server room [Jinkyun Cho *et al*].

They are defined as follows:

$$\mathrm{DCiE} = \frac{EnergyOfITEquipment}{TotalEnergyOfDataCenter} \quad (1)$$

$$\mathrm{PUE} = \frac{TotalFacilityPower.}{TotalITPower.} \quad (2)$$

B. Server room Thermal Management:

1)The necessity for air flow efficiency analysis

The basic flow of server room's air management starts with air supply from the CRAC unit to IT server, heat removal, and ends with hot air return back to the CRAC unit. However, in reality, air streams are obstructed by factors, such as air re-circulation or by-pass, as shown in Fig. 2, decreasing cooling efficiency and creating vicious cycle of rise in local temperature. The IT server room, which is the most critical space in a server room, is generally designed to the international standard. In addition, layout of IT servers (racks) is designed to minimize air re-circulation, mixing, by-pass, etc., to separate airflow of IT equipment's supply air in the cold aisle from exhaust air in the hot aisle. Furthermore, spacing requirement follows the global design standard. There-fore, once the data center's level is decided, architecture, such as floor plan, section, etc., is generally similar within a certain boundary. In order to analyze the air distribution efficiency of a data center, the most objective method of evaluation is through the performance index [H.S. Sun*et al*].

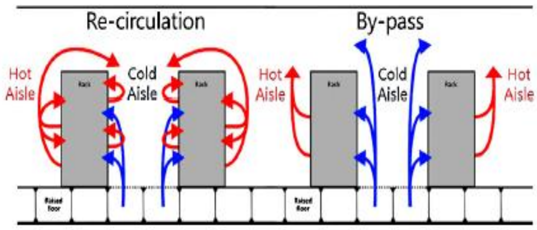


Figure 2: Out of control airflow in server rooms; re-circulation and by-pass airflow [Yiqun Pan *et al*].

It is important to evaluate the adequate supply of air temperature to reduce the heat load in the servers based on the server room's design standard. In the past, design standard used to focus on the IT equipment's reliability, but wasted energy, such as over cooling, has also become a significant evaluation factor in recent days. It is possible to derive an overall performance index of cooling efficiency through objective evaluation by adjusting design variables, such as IT server rooms architectural and mechanical design elements, etc. from traditional data center design requirements [JinkyunCho*et al*].

2)Airflow performance and efficiency of data centers:

The main task in a data center is to provide adequate environment for equipment, where a relevant metric for equipment intake temperature should be used to manage the thermal environment. This paper takes the analysis one step further and air distribution scheme is used to demonstrate RCI and RTI given the fact that the air distribution from a raised floor is by far the most common way of cooling in data centers.

3)Rack cooling index (RCI)

The original work of RCI's complete description was carried out. This index is associated to rack intake temperatures, which is the condition air-cooled IT server requires for continuous operation.

The allowable range and recommended range for intake temperature as shown in fig. (3). It represents design conditions, where the recommended limits refer to the preferable facility operation. Over-temperature conditions exist if one or more intake temperatures exceed maximum recommended temperature. The total over-temperature represents a summation of over temperatures across all rack inlets. Similarly, under-temperature conditions exist when intake temperatures drop below the minimum recommended. The RCI consists of two parts, which is describing the IT sever room heat that the high end and at the low end of the temperature range, respectively. The RCI_{HI} definition is [A.H. Beitelmal*et al*]

$$RCI_{HI}=\left[1-\frac{\text{Total over temperature}}{\text{Max allowable over temperature}}\right]\times 100\%$$

$$RCI_{HI}=\left[1-\frac{\sum\left(T_i-T_{\max-rec}\right)_{T_i \geq T_{\max-rec}}}{n\times\left(T_{\max-all}-T_{\max-rec}\right)}\right]\times 100\,\% \tag{3}$$

The RCI_{HI} measures the difference of over-temperatures, where 100% means that no over-temperatures exist. The lower the percentage, the greater the probability the equipment experiences above maximum allowable temperature. The two indices can preferably be used in tandem. On the other hand, if an under temperature is of less concern, the focus should be on maximizing the RCI_{HI}. The RCI_{LO} is defined as Eq.:

$$RCI_{LO}=\left[1-\frac{\text{Total under temperature}}{\text{Max allowable under temperature}}\right]\times 100\%$$

$$RCI_{LO}=\left[1-\frac{\sum\left(T_{\min-rec}-T_i\right)_{T_i \leq T_{\min-rec}}}{n\times\left(T_{\min-rec}-T_{\min-all}\right)}\right]\times 100\% \tag{4}$$

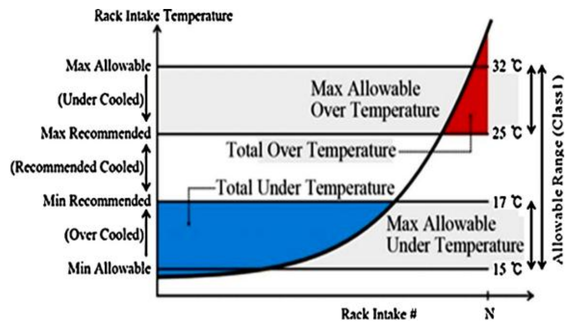


Figure 3: Definition of total over-temperature and total under-temperature (ASHRAETC 9.9, 2008)

4)Return temperature index (RTI)

In data centers of open architecture, the RCI_{HI}can be improved by increasing the supply airflow rate and lowering the supply air temperature. However, these measures are associated with negative consequence related to energy. The RTI is a measure of energy performance in air management system. The index is defined as Eq.:

$$RTI = \left[1 - \frac{T_{return} - T_{supply}}{\Delta T_{equipment}} \right] \times 100\% \qquad (5)$$

A value above 100% suggests net re-circulation air is higher than return air temperature. Unfortunately, this also means elevation of equipment intake temperatures. A value below 100% suggests net by-pass air, which indicates cold air by-passed the electronic equipment, returned directly to the CRAC, hence, reduced the return temperature.

2. Cooling Method for Server Room

The purpose of the cooling system in a server room is to meet the temperature requirements of the electronic equipment installed within the server room. As shown in fig. (4) Server racks are arranged into hot and cold aisle's, that partially separate. The cold air exiting the perforated tiles or floor grills from the hot air exhausting from the rear of the racks. As shown in fig. (4) Racks are positioned in such a way that the front side of the racks faces each other hence between two rack cold air flow & cold air suck by rack in cold aisle. Similarly, the rear sides of the racks face each other and provide a common hot air exhaust region.

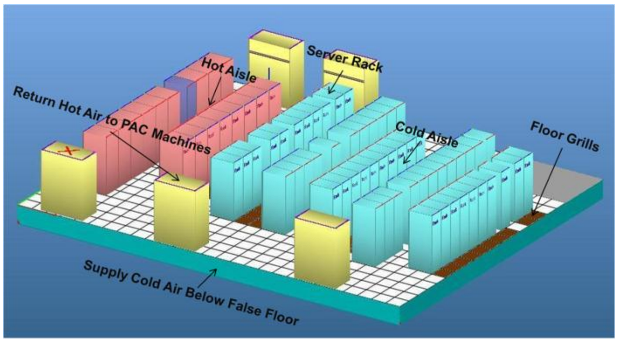


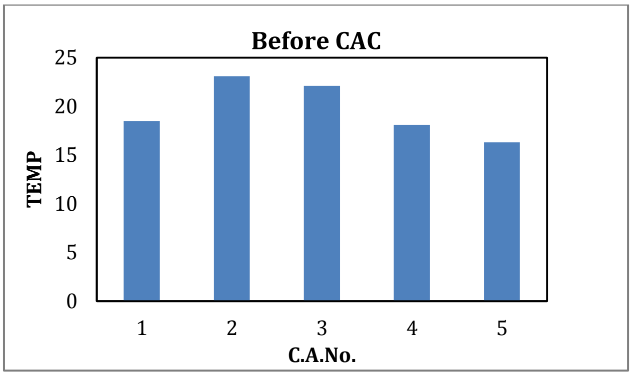
Fig.4 Hot aisle - cold aisle server rack configuration in a typical server room

The cold air flow through perforated tiles or floor grill, after the cold air supply has passed through and equipment rack and picked up the dissipated heat. The hot air stream may then return to the neighboring rack and subsequently nullify the effect of cooling from vent tiles. This phenomenon, known as recirculation is very common in the internal areas of the server room where the equipment density is high. Hot air recirculation is often extremely complex in nature to analyze and can cause hot spots. Where server racks inlet temperature is significantly higher than expected. The existence of hot spots can be detrimental to the performance and reliability of electronic equipment's [A.H. Beitelmal*et al*]. To avoid increase in inlet temperature of the server rack units due to hot air recirculation, server room operators often enable additional cooling capacity and by minimizing the PAC supply temperature and increase the PAC flow rate. Although this phenomenon may not be detrimental to the performance or reliability of electronic equipment, it increases cooling energy consumptions [Yiqun Pan *et al*]. To avoid this issue we need to use cold aisle containment cooling (cabinet cooling) methodology for server room. In this, the cabinet manufactured by flexible fire retardant PVC Strips/Sheets supported by MS Steel powder coated door frame with 4 mm thick fire retardant polycarbonate sheet after done this retrofitting as per server room layout checked the thermal behavior of server room and energy consumption (i.e. PUE &DCiE).

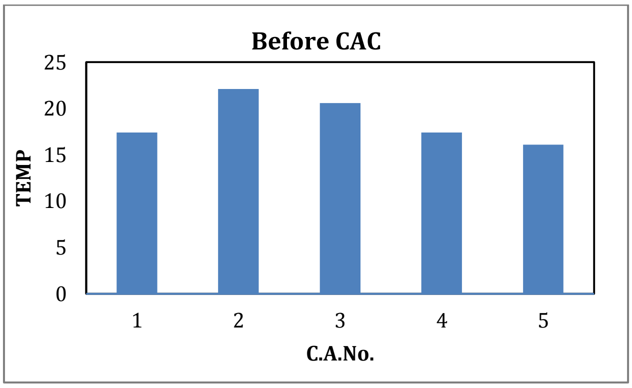
3. Experimentation

As shown in fig. 4 (Hot aisle - cold aisle server rack configuration in a typical server room.) it contains PAC of capacity 17TR which is installed at the perimeter area of server room. As per redundancy criteria we considered four working & one standby system in this area but because of recirculation of hot air all the PAC machines is in running condition for achieving desired temperature in server room. As we have discussed, the chances of inefficient cooling is due to hot air mixing issue for that we had carried out experiment. The parameter which causes problem of inefficient cooling in server room is measured. We have measured the temperatures at location of T1, T2, and T3 in cold & hot aisle. The graph of temperature measurement is as fallows,

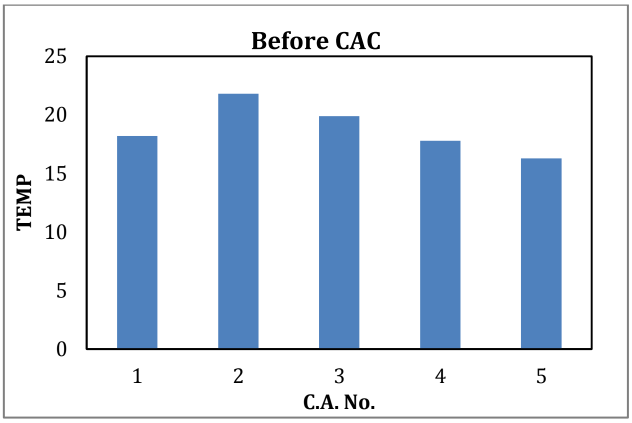
The graph of temperature measurement before CAC



Graph.1:- Temperatures of Before CAC Vs. Cold Aisle No at 3.6 M Distance



Graph.2:- Temperatures of Before CAC Vs. Cold Aisle No at 6.6 M Distance



Graph.3:- Temperatures of Before CAC Vs. Cold Aisle No at 9.6 M Distance.

From graph (1),(2) & (3) of temperature it is cleared that the temperature in cold aisle number two & three is near about 22^{0}C to 23 ^{0}C which is near to ASHARE maximum recommended range for server room[Yiqun Pan *et al*].Which caused hot pockets generated in server room. This generation of hot spot is forms due to hot air recirculation in cold aisle and its increases the inside temperature of server room.

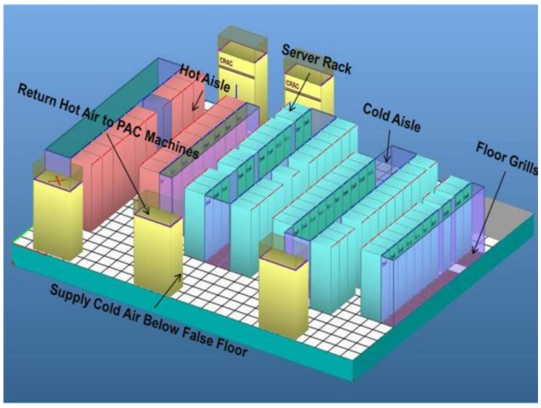
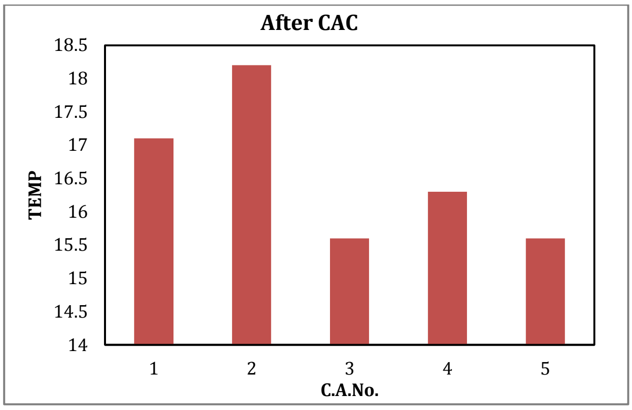


Fig.5 Hot aisle - cold aisle server rack configuration in a typical server room after CAC

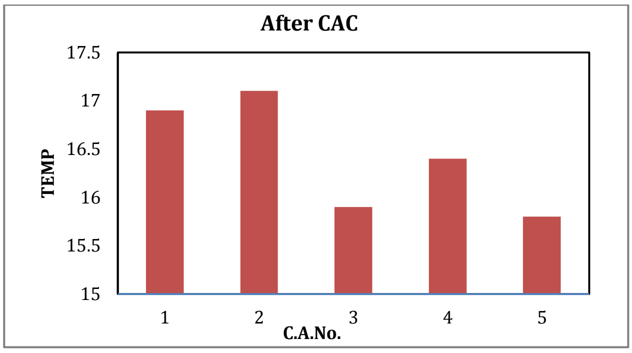
For this air mixing issue (as shown in fig. 5), we have applied segregation cooling methodology.In this cooling method, separate air path for cold air is given and this cold air supply in the cabinet in cold aisle. due to separate segregated air path given to cold air, the chance of air mixing issue is reduces. This methodology is known as cold aisle containment. After cold aisle containment we again check the temperature in each cold aisle. These temperature observations are shown in graph (4), (5), & (6).

It is observed that, there is improvement in thermal profile of server room (The average reduction in temperature of cold aisle is near about 3^{0}C).

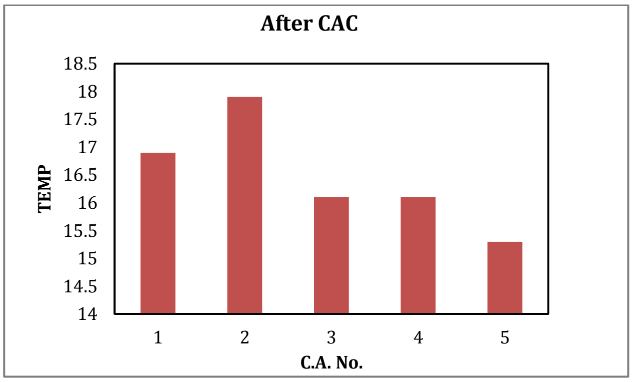
The following graph shows the percentage of net hot air recirculation before and after cold aisle containment. From graph 7 & 8 on X-axis cold/hot aisle no's given while on Y-axis return temperature index value given.



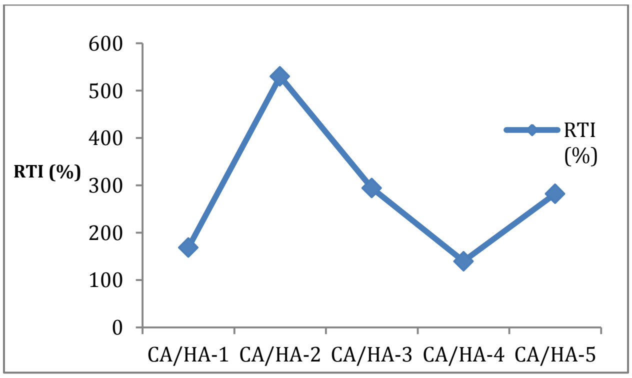
Graph.4:- Temperatures of After CAC Vs. Cold Aisle No at 3.6 M Distance.



Graph.5:- Temperatures of After CAC Vs Cold Aisle No at 6.6 M Distance.

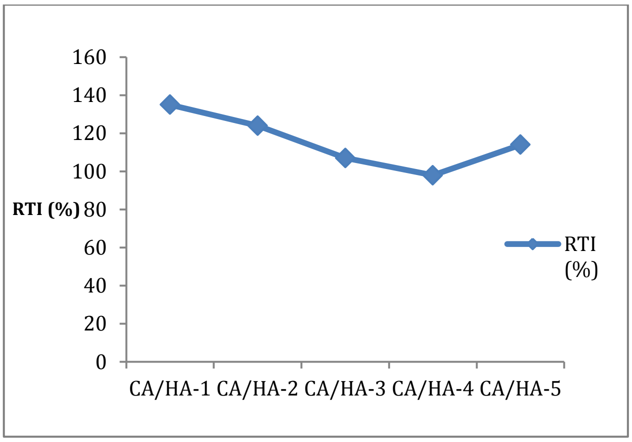


Graph.6:- Temperatures of After CAC Vs Cold Aisle No at 9.6 M Distance.



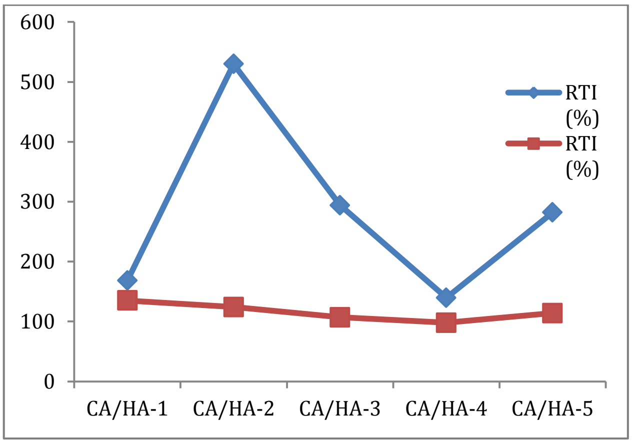
Graph 7: Return temperature index Vs. CA/HA Nobefore cold containment

The graph 7 shows the net recirculation of hot air before cold aisle containment. From this graph it's clear that the value of return temperature index (RTI) is increased in cold/hot aisle 2, 3 & 5.Therefore the net of recirculation hot air is more in this zone.



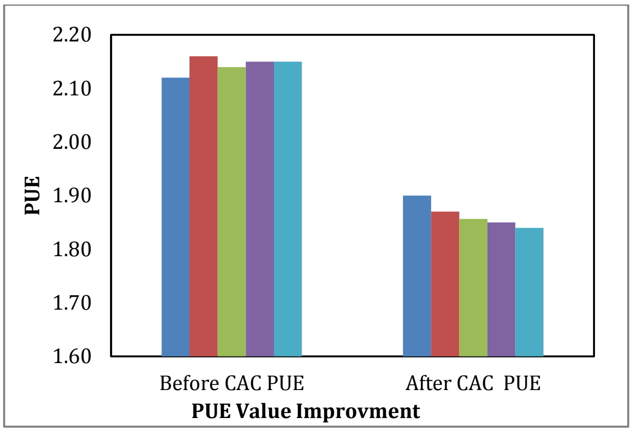
Graph 8: Return temperatures index Vs. CA/HA no after cold containment.

The graph 8 shows the net recirculation of hot air after cold aisle containment. From this graph it's clear that the value of return temperature index (RTI) is reduced in cold/hot aisle 2, 3& 5.Therefore there is reduction in net recirculation hot air in this zone.



Graph 9: Return temperatures index Vs. CA/HA no after cold containment

The graph 9 shows the comparison of net recirculation of hot air before & after cold aisle containment. From this graph it's clear that the maximum reduction in value of return temperature index (RTI) is observed. Following graph 10 shows month wise comparison of PUE of server room before & after cold aisle containment from Power Usage Effectiveness graph, it is observed that, there is improvement in energy efficiency of server room about 14.89% after cabinet cooling method used.



Graph.10: Comparison of before & after CAC PUE

Conclusions

In this paper, dedicated air distribution systems and its impact on energy-saving are discussed. The main objective of this work is defined by numerical and energy analysis process to assess each technical component's influence in order to create energy-optimized server room. The temperature and energy analysis calculation results largely impacts the energy consumption. The main conclusions of this paper are as follows.

1) There are many reasons why server rooms should be treated differently from other types of occupied buildings. As the energy consumption trend is maximum than other commercial infrastructure. One of the reasons is that inefficient air distribution system is used in server room. In server room cooling systems maximum chances of recirculation of hot air which forms hot spots in server room.
2) The hot air recirculation is calculated from thermal performance index metrics i.e. Return Temperature Index (RTI).The average value observed in server room before cold aisle containment is 283% while this value drop down to 116% after carried out retrofitting of cold aisle containment. This reduction in hot air recirculation impact on temperature in cold aisle. The average drop in temperature of cold aisle is 3ºC.
3) This work investigated the feasibility of reducing energy consumption by maintaining a comfort condition as per ASHRAE thermal guideline for server room.
4) The increase in operating temperature on the results obtained of thermal behavior of server room improves the energy consumption of server room. The reduction in value of power usage effectiveness is observed. PUE before cold aisle containment is 2.14 while it reduced to 1.86.
5) The improvement in server room infrastructure efficiency is observed due to reduced hot air recirculation by applying cabinet cooling. The value of server room infrastructure efficiency is

47% before cold aisle containment. It is increased to 54% after retrofitting is done. Finally it is conclude that 14.89% improvement achieved in server room infrastructure efficiency.

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