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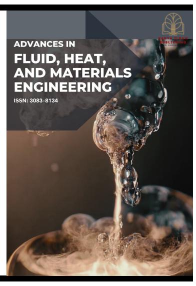

Thermal Distribution and Airflow in Data Centre At Uthm: Pusat Teknologi Maklumat, Block A5

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ABSTRACT

This research work is concerned with the investigation of thermal management and air circulation in the data centre at Universiti Tun Hussein Onn Malaysia, which is situated in Block A5. The facility has no windows, natural ventilation, or air conditioning systems, making it difficult to achieve and maintain appropriate temperatures for storing and processing data. The disparity in temperature felt in the centre called for enhancing the cooling systems as a means of enhancing the efficiency and durability of the equipment. The simulations focused on temperature distributions at different heights of the data centre, including the middle of the room and at one-quarter and half heights. Furthermore, the rack cooling index (RCI) was used to measure the rack cooling performance in accordance with the ASHRAE guidelines on data centre cooling. The results revealed significant variations in the temperature pattern, with some server racks having higher heat densities and the cooling units nearby having to work harder to achieve the set temperatures. Such an imbalance in the cooling system requires strategic changes. To improve the cooling performance, specific suggestions were made, such as increasing the airflow from some air-conditioning units to address hot spots. These changes should help mitigate moderate temperature fluctuations within the data centre and in turn improve the efficiency of the cooling system. The proposed strategies for controlling the airflow and cooling aim at reducing the energy consumption and increasing the lifespan of critical server components. Finally, this study highlights the need for customized cooling systems in data centres and offers practical recommendations for enhancing the sustainability of data centre cooling systems.

1. Introduction

Data centres are centralized facilities where computing, networking equipment and data storing is concentrated for collecting, storing, processing, distributing and allowing access to large amounts of data [1]. Data centre provides important services which is essential for UTHM to have this centre where data storage, backup and recovery, data management as well as networking are all connected

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to this data centre. As data are stored in this data centre, the cooling infrastructure inside the data centre is also important [2,3]. Cooling infrastructure in data centre is crucial, where proper cooling and air circulation inside data centre will create the best computing environment, ensure the long life of servers and equipment within. Common cases of data centre cooling infrastructure are the incapability of handling the additional cooling requirements, which results in unwanted conditions such as recirculation or mixing of hot and cool air [4]. Poorly controlled humidity and costly wasted cooling capacity [5,6]. Universiti Tun Hussein Onn Malaysia (UTHM)'s main data centre is located at Information Technology Centre building at Block A5, which has no windows, ventilation and minimal fresh air due to the fact that this centre is primarily designed for IT equipment and not for staff. An observation was made at UTHM Data Centre, it was found that the cooling infrastructure inside the data centre is not well distributed and arranged. It was also found that the UTHM Data Centre did not equipped with an underfloor supply and no exhaust. The study also observed that several split units of air conditioners were placed apart from the central unit supplied. Because of this, several parts of the room felt colder than the other parts, especially the area where the split unit air conditioner outlet vents. Therefore, it is important to determine the best possible layout for cooling strategies to evenly distribute the airflow to provide an even temperature distribution around the data centre room.

The standard on telecommunications infrastructure for data centres of Telecommunications Industry Association defines the minimum standards for data centres' and computer facilities, including single-tenant company data centres and multi-tenant internet-hosting data centres. The proposed topology can be applied to information centres of any size [7]. Telcordia GR-3160, NEBS Requirements for Telecommunications Data Centre Equipment and Spaces, provides guidelines for data centre spaces within telecommunications networks and environmental requirements for equipment intended for installation in those spaces [8]. These criteria were jointly developed by Telcordia and industry representatives. They can be applied to data centre spaces housing data processing or information technology (IT) equipment [9]. The equipment can be used to operate and manage a carrier's telecommunication network. Provide data centre based applications directly to the carrier's customers. Provide hosted applications for third parties to provide services to customers. Provide a combination of these and similar data centre applications. Local building codes may regulate ceiling heights and other parameters [10]. Some of the considerations from the precious research were reviewed, including the design of data centres are: size-one room of a building, one or more floors or an entire building, and can hold 1,000 or more server space, power, cooling and costs in the data centre. Mechanical engineering infrastructure-heating, ventilation, and air conditioning (HVAC); humidification and dehumidification equipment; pressurization [11]. Electrical engineering infrastructure design-utility service planning; distribution, switching, and bypass from power sources; uninterruptible power source (UPS) systems; and more [12].

Next, air flow management addresses the need to improve data centre computer cooling efficiency by preventing the recirculation of hot air exhausted from IT equipment and reducing bypass airflow. Based on previous studies, several methods have been proposed for separating hot and cold airstreams, such as hot/cold aisle containment and in-row cooling units with aisle containment. The rear of the equipment racks is exposed to the room, while the aisles containing the fronts of the servers are enclosed with doors and covers, indicating that cold aisle containment is being practiced [13,14]. Air streams are obstructed by many factors. Such examples include air recirculation or bypass, decreasing cooling efficiency, and creating a vicious cycle of rising local temperature [15,16]. The server room, which is a critical area in data centre is generally designed based on international standards [17]. The layout is designed to minimize air recirculation, mixing, and bypass to separate the airflow between the cold and hot aisles [18].

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The main task in a data centre is to provide an adequate environment for equipment. To analyze the air distribution, the rack cooling index (RCI) approach was used to determine the temperature range inside the data centre at PTM and to compare the results with those of the ASHRAE standard. The RCI was computed using the average number of degrees that the rack inlet temperature fell above or below the ASHRAE recommended temperature range (18℃-27℃).

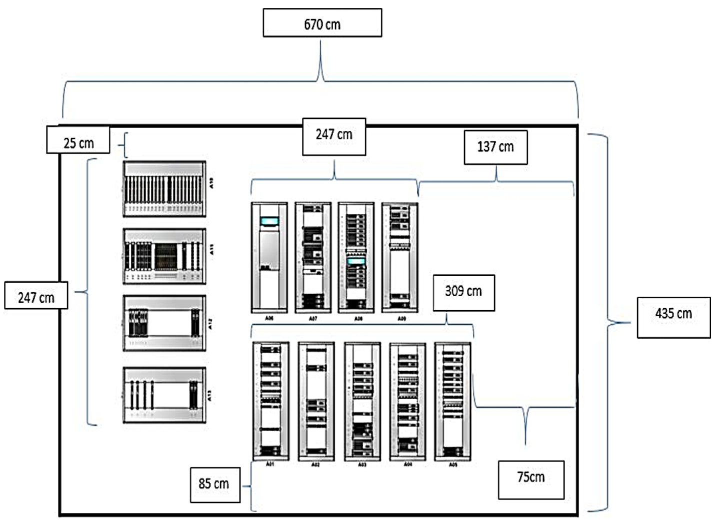
The computational fluid dynamics (CFD) software tool was used for the simulation. Fluent is a large computer program for modelling fluid flow and heat transfer in complicated domains [19]. It also provides mesh flexibility and is suitable for flow problems involving various geometries [20]. The design of this project considers the necessary data. To achieve the objective of the selected area, the Information Centre of Information Technology (PTM) at UTHM was selected as the scope of study. PTM is located in building A5. The rough frame was created as a reference for the model in Solidworks and was included in the CFD application.

2. Methodology

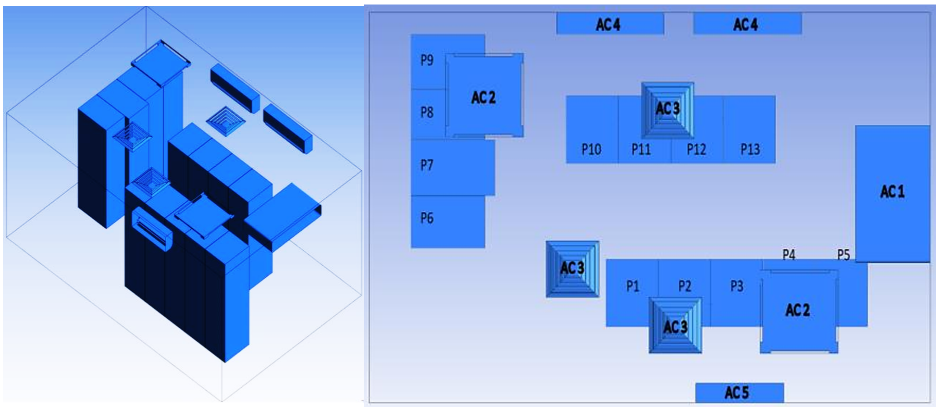
There are three main stages in CFD: preprocessing, solver, and postprocessing. The preprocessing stages involve the geometries and meshing analysis of the model, where the geometry of the monitor panels and control room can be drawn using Solidworks software and then imported into CFD. Next, the geometries will be meshed, and the flow structure is verified. In the post-processing stage, solution-solving using a solver is employed to solve the governing equation, which involves data gathering as well as the visualization of the data and result. The data and results will be discussed simultaneously.

2.1 Description of Model

The project design involves collecting the necessary data. To achieve the objective in the selected area, the Information Centre of Information Technology (PTM) at UTHM was chosen as the scope of study. PTM is located in building A5, focusing specifically on the A5 server room. A preliminary model has been created in the SolidWorks application, which will be used as a reference in the CFD application. Figure 1 shows the detailed dimensions of the panels, and the average temperatures are given in Tables 1 and 2.



(a)



(b) (c)

Fig. 1. Detailed dimensions of the panels (a) Dimension of the panel (b) 3D view (c) Top view

Table 1
List of panels and labels with dimensions and temperatures measured inside data centre

Panel description	Dimension (length x width x height)	Inlet temperature (°C)
P1	62 x 75 x 200	38.55
P2	62 x 75 x 200	43.30
P3	62 x 75 x 200	38.43
P4	62 x 75 x 200	32.48
P5	62 x 75 x 200	32.05
P6	88 x 58 x 200	31.00
P7	100x 62 x200	30.00
P8	88 x 56 x 200	27.00
P9	88 x 60 x 200	30.00
P10	62 x 75 x 180	33.80
P11	62 x 75 x 180	34.50
P12	62 x 75 x 180	31.08
P13	62 x 75 x 180	32.63

Table 2
List of air conditioner dimensions and temperature labels measured inside data centre

Air conditioner description	Dimension (length x width x height)	Air flowrate (kg/s)	Temperature (°C)
AC 1	153 x 89 x 25	0.504 1	16
AC 2	93 x 93	0.231 3	16
AC 3	60 x 60	0.231 3	16
AC 4	128 x 24 x 30	0.231 3	16
AC 5	105 x 22 x 31	0.132 9	16

2.2 Meshing

A digital volume representing the three-dimensional geometry (see Figure 2) was designed in scale 1:1. A discretization grid of 12,467,923 tetrahedral cells with edge refinement and mapped mesh on mappable faces was applied, as in the simulation.

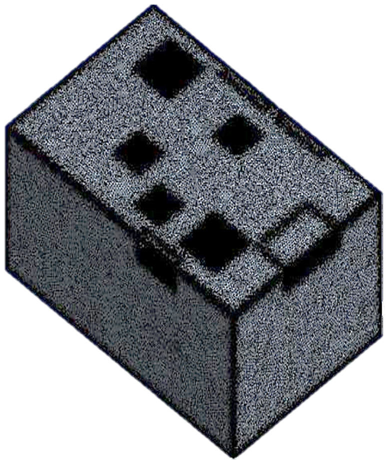


Fig. 2. Meshed model of the data centre with edge refinement and mapped mesh

2.3 Governing Equation

For the analysis of thermal distribution and airflow in the data center, the following governing equations are typically used in Computational Fluid Dynamics (CFD) simulations.
Continuity Equation

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho v) = 0 \quad (1)$$

where ρ represents the density and v is the velocity. This equation ensures the conservation of mass in the airflow within the data center. Momentum equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho v) = -\nabla \rho \ + \nabla \cdot (\mu \nabla v) + F \quad (2)$$

where ρ represent density , v denotes the velocity vector, μ dynamic viscosity of the fluid , and F is the external forces acting on the fluid , such as gravity or other bodies. These equations describe the momentum transfer in the airflow, accounting for the effects of pressure, viscous forces, and external forces (such as gravity). Energy equation:

$$\frac{\partial (\rho E)}{\partial t} + \nabla \cdot \big(v(\rho E + p)\big) = \nabla \cdot (k + \nabla T) + \ \Phi \quad (3)$$

where ρ represent the density of the fluid, T is the temperature, E signifies the total energy per unit mass, k is thermal conductivity and and Φ represents the dissipation function. This equation accounts for the energy transfer due to conduction, convection, and viscous dissipation. Heat transfer equation:

$$\rho C_p \left(\frac{\partial \rho}{\partial t} + v \cdot \nabla \mathrm{T}\right) = k \nabla^2 \mathrm{T} + \mathrm{S} \quad (4)$$

where ρ represent the density of the fluid, T is the temperature, k is thermal conductivity and S is internal heat sources (such as the heat generated by servers). This equation describes the heat transfer within the server room considering the conduction, convection, and internal heat sources

3. Results

3.1 Heat Propagation in the Room and Panels

Figure 3 shows the heat propagation through the entire room and panels. The heat is dissipated from the panel flow into the larger space and is then recirculated into the cold aisle. Typically, the flow of air passes through the vent tiles into the cold aisle, where the cold air is moved into the server inlets and out of the back of the servers into the hot aisle. The hot air is then transferred to the sides of the room until finally absorbed by the air conditioner. Such hot temperature zones cause a rise in temperature, leading to reliability issues for electronic components. Hence, it is important to employ a proper cooling solution to keep the temperature within the required limits. Therefore, the hotspot located near panel 2 is discussed in greater detail later.

Figure 4 shows the streamline of the airflow for different types of air conditioner. It can be clearly observed that the air flow passes through all panel components. However, at a certain location located between panels 6, 7, 8, and 9, there is less streamline of air flow, which means that the cooling at that point is low. However, the heat propagation at this point is acceptable because the temperatures in panels 6, 7, 8, and 9 are low (approximately 27-31°C). Therefore, there is no problem because the cooling air from the air conditioner is sufficient to cool the panel.

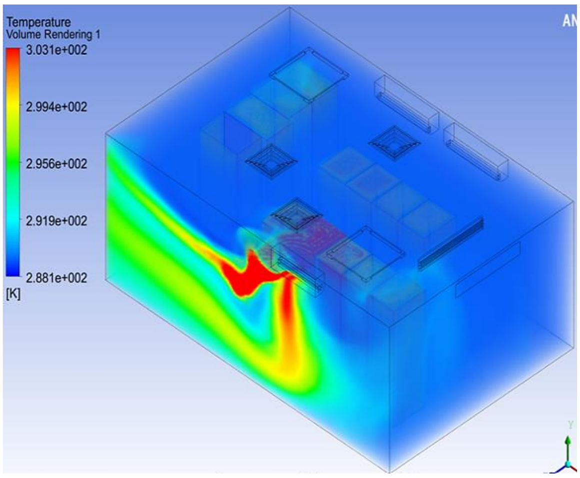


Fig. 3. Heat propagation through all rooms and panels

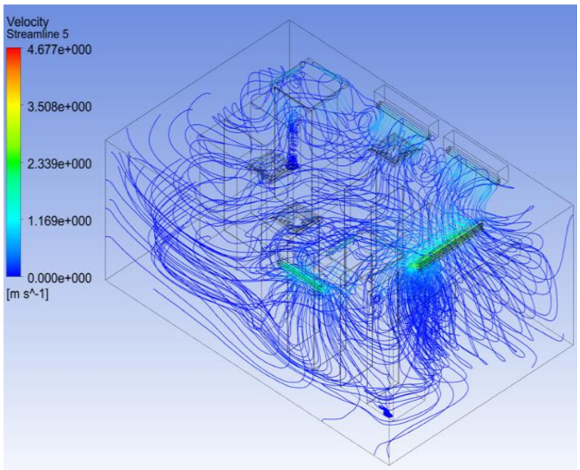


Fig. 4. Streamline of airflow from different types of air conditioner

3.2 Heat Propagation in the Room and Panels for 25, 50 and 75 Percent

Figure 5 was analyzed in x-z plane to observe the contours of the heat profiles. Three different contour heat profiles are shown, which are 25, 50 and 75 percent from the total height of the room, with heights of 63.25 cm, 126.5 cm and 189.75 cm, respectively. The temperature range was approximately 16°C to 30°C before data collection. Therefore, the maximum temperature indicated in the figures is only 30°C. This occurs because the component has its own limit temperature before failure or its life cycle is reduced.

From Figure 5(a), the heat dissipated from all panels is approximately the same, except for panel 2. The heat propagation was clearly observed at high temperatures near panel 2. The panel indicates the temperature of 43.3°C and air flow from 3 different air conditioners with a temperature constant of 16°C. The air flows from three different air conditioners near to this panel were AC 2, AC 3, and AC

5, with air flows of 0.2313, 0.2313, and 0.1329 kg/s, respectively. The hot air from panel 2 passes through near the wall, where there is a cold aisle.

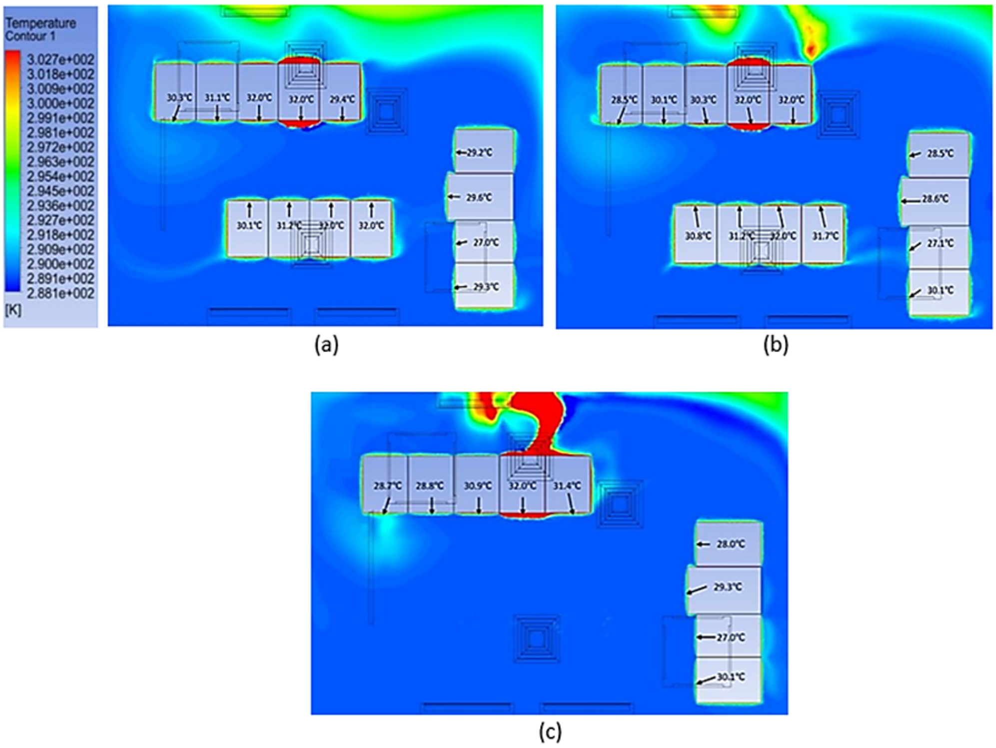


Fig. 5. Thermal profile (a) 25% height (63.25 cm) (b) 50% height (126.5 cm) (c) 75% height (189.75 cm)

Figure 5(b) shows the contour of the heat profile at 50 percent height. As the height increases, the heat of the thermal map is slightly higher than 25 percent. The panel number indicates the same heat propagation because it is the average temperature of a given panel. The hot air can be seen below air conditioner number 5 and near panel number 1, which indicates a temperature of 28°C. Figure 5(c) shows that the temperature rise was more evident at higher heights (189.75 cm) than at lower heights (63.25 cm and 126.5 cm). It can be noticed from the figure that the maximum temperature is located between panel 2 and the wall below air conditioner number 5. The air temperature was also the same at this height because the angle of the air conditioner removed only heat from the bottom side.Thus, air flow is not efficiently supplied to cool the entire room, and for most at the hotspot.

3.3 Evaluation of RCI Over Temperature

The RCI over temperature was calculated to analyze the experience of panel equipment exposed to over temperature. If the RCI value lies below 90%, then the probability of the equipment being harmful from thermal exposure is higher and increases relatively with decreasing RCI percentage. The RCI for low-temperature conditions is not included because the inlet temperatures of the panels are not monitored continuously. For the maximum inlet temperature for RCI over temperature, the temperature achieved from the CFD simulation was used to compute the rack cooling index. Below is the evaluation of RCI over temperature using the formula provided by ASHRAE. Table 3 presents an evaluation of the RCI over temperature using the obtained CFD simulation data.

The calculated RCI shows in the table indicated that as the panel go higher, the exposure under over-temperature is increasing. Therefore, to reduce the exposure temperature value, the airflow of the air conditioner must perform more efficiently than the current situation so that the component will have a longer life and also will reduce the server lag or fatigue.

Table 3
Evaluation of RCI over temperature using CFD simulation data

Height (%)	Total over-temperature (°C)	Maximum allowable temperature (°C) (N= rack)	RCI_{HI} (%)
25	44.2	67.86 (13)	65.13
50	41.9	67.86 (13)	61.74
75	23.2	46.98 (9)	49.38

4. Conclusions

Based on the simulation of the real height, the heat propagation inside the server room is unbalanced where one side of the room has a higher heat propagated. The place where server blocks P1 to P5 is located. The other place where server blocks P6 to P9 and P10 to P13 has a cooler area. The unbalanced heat propagation in the server room area may affect the air condition system. AC5, AC2 and AC3 that is near to server blocks of P1 to P5 have to work more because of the heat released from it. While, AC4, AC2 and AC3 that is near to P6 to P9 and P10 to P13 have less work. It shows that the air conditioning system in the room is unbalanced and not very efficient. The height of the room also effects the heat propagation where at the 75 percent of the height shows higher temperature than 50 and 25 percent. As mention in the discussion, AC3 should increase its air flow so that the problem of high temperature area in the server room solve. Hence, improved the air condition system or cooling performance of the server room. Therefore, the energy efficiency for the server room will increase.

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