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Effect of CRAC units layout on thermal management of data center

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HIGHLIGHTS

- CFD study of thermal management in data centers.
- Effects of layout arrangements of the CRACs units relative to the racks array on data center performance.
- Design guide liens for data centers energy efficiency improvements.

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ABSTRACT

Comprehensive numerical studies of thermal management of data centers were presented by several investigators for different geometric and operating conditions of data centers. In the present work, a technical note regarding the effect of the computer room air conditioning (CRAC) units layout arrangements is presented. Two arrangements of CRAC units layouts are investigated; namely locating CRACs units in line with the racks row and locating the CRACs units perpendicular to the rack row. Temperature distributions, air flow characteristics particularly air recirculation and bypass and thermal management in data centers are evaluated in terms of the measureable overall performance parameters: supply/return heat indices (SHI/RHI) and return temperature indices (RTI). The results showed that locating CRAC units perpendicular to the racks row has the following effects: (i) enhances the uniformity of the air flow from the perforated tiles along the rack row, (ii) reduces the hot air recirculation at the ends racks of the row and the cold air bypass at the middle rack of the row and (iii) enhances the data center performance parameters RTI, SHI and RHI.

1. Introduction

Increasing data centers servers density, reducing servers sizes and maintaining energy efficiency represent a challenge of the air conditioning designer of data centers. Efficient air distribution and thermal management in data centers are the key factors to solve this challenge. In recent years, energy consumption by data centers servers and their cooling system was doubled leading to a critical concern of the electricity usage [1]. The increase of server's power density led to the increase in energy consumption of cooling systems to approximately 40% of data center's energy consumption [2,3]. Hot air recirculation and cold air bypass around the server's racks are the main problems to reliable operation and energy consumption of data centers (see Fig. 1).

Servers located at the bottom of servers racks are expected to receive cold air and servers located at the top of racks and ends of racks row may receive hot recalculated (see Fig. 1). Hot air recirculation results in high server's intake air temperature leading to hot spots in servers. Typically, pushing more air flow through the perforated tile or lowering the tile air flow temperature is used to avoid high servers intake temperature. In this case, the bottom servers will be over-cooled resulting in wasted cooling energy. Maintaining efficient airflow distribution for cooling of IT servers can provide high cooling efficiency with minimal effort. Servers racks and CRAC units layout arrangements strongly affect air flow and temperature distribution inside the data center.

Most of recent data centers studies are devoted to solve hot air recirculation problem and minimize cooling system energy consumption. There is a recent interest in performing data center studies using CFD tools validated with experimental data. Kang et al. [4] showed that a simple model of the volume of data center raised floor using the technique of flow network modeling (FNM) can predict the air flow distribution exiting from the various tiles. Schmidt et al. [5] numerically investigated the effect of raised-floor plenum depth and percentage of tiles perforation area on airflow rates through the perforated tiles for different arrangement of data center. They showed that 20% opening ratio and 60 cm plenum depth

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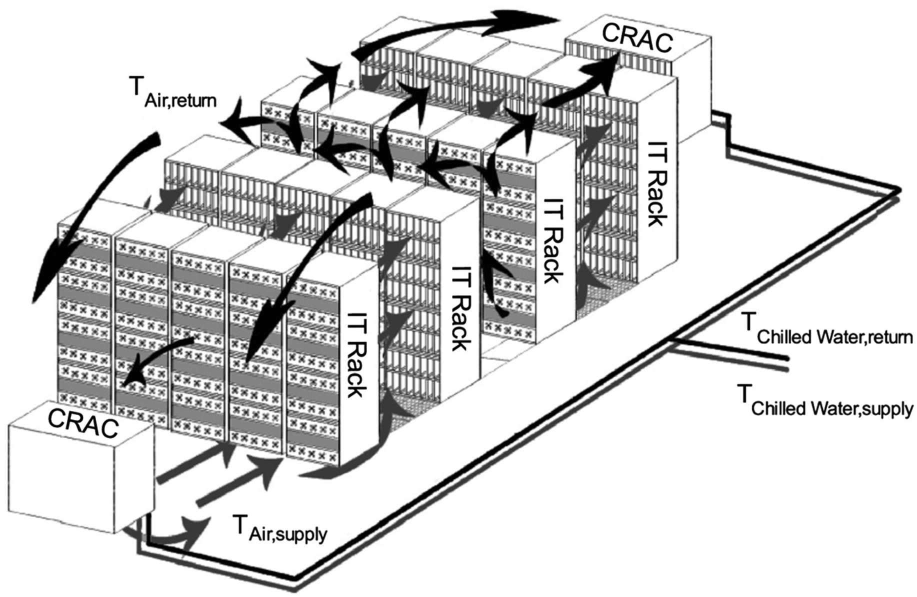

Fig. 1. Example of a typical data center [3].

leads to data center optimum performance. Karki et al. [6] presented a CFD model for predicting perforated tiles airflow rates in raised-floor data centers. To limit the calculation to only the raised floor space, the pressure in the space above the raised floor is assumed to be uniform. Abdelmaksoud et al. [7] reported that including of correct tile flow model, buoyancy, and realistic turbulent boundary conditions in the model are strongly improve data centers CFD simulation results. A momentum source model for tile flow was developed to correct mass and momentum modeling of air jets from the perforated tiles. Kim [8] presented a CFD study for air flow distribution in data centers for fan-assisted floor tiles and floor tiles with louvers. The fan-assisted tile was used to enable a variable local tile flow rate. The study recommended a control system for the active tile to avoid hot spots at a particular severs of the racks. Schmidt and Cruz [9] studied the effect of the distribution of airflows exiting the perforated tiles on rack inlet air temperatures. A computational fluid dynamics (CFD) tool called Tileflow (trademark of Innovative Research, Inc.) was used to generate the flow distribution exiting the perforated tiles. The effects of raised floor depth and perforated tile-free areas on rack inlet temperatures were also investigated. Cho et al. [10] conducted CFD simulation analysis in order to compare the heat removal efficiencies of various air distribution systems in a high heat density data center. Schmidt [11] numerically studied the effect of datacenter design parameters of actual data center floor plans on the uniformity of the perforated tile airflow using CFD model verified by experimental test data. It was found that decreasing the plenum depth leads to a reverse flow at perforated tiles near the CRAC units. Bhopte et al. [12] conducted a numerical parametric study to the effect of plenum depth, floor tile placement and ceiling height on the air flow distribution and thermal management of 12 kW racks power density. Karki et al. [13,14] used an idealized one-dimensional CFD model to study the effects of plenum depth and the opening ratio of the perforated tiles on the airflow distribution. The results showed significant variations in airflow distribution when changing plenum height or tile open areas. Sharma [15] studied the effects of cold aisle and hot aisle widths and ceiling space on data centers thermal performance. The study showed that data centers can be optimized not only based on geometric parameters but also based on heat loads using the non-dimensional parameters supply heat index (SHI) and return heat index (RHI) to evaluate the thermal design and performance. Ibrahim [16] conducted numerical study to investigate the effects of power density and IT servers thermal mass on airflow and thermal management of data center. The results showed that servers mass dictates how slowly or quickly the facility temperature rises or falls. More recently, Nada et al. [17–24] presented comprehensive numerical and experimental studies suing scale physical model to investigate the effects of power density, floor tiles opening ratio, lateral space between the CRAC unit and cold aisle, power loading conditions of servers and the using of cold aisles containments and partitions on the uniformity of the air flow, cold air bypass and hot air recirculation, temperature distribution around the servers of the racks, and the thermal management performance parameters (RTI, SHI, RHI and RCI). It was shown that (i) using cold aisle partitions with raised floor decreases the recirculation and bypass of air flow around the middle and first racks in a rack row, respectively and improves the performance of data center cooling system, (ii) using control of servers fans speeds improve the data center performance parameters and eliminate the possibility of hot spots existence.

The current literature illustrates that studies on the effects of CRAC units location, layout and arrangements inside the data center on air distribution, temperature distribution and thermal management of data centers are not available. In the present technical note, the effects of CRAC units layout arrangements on the air flow characteristics and thermal performance of the data centers are investigated. Supply/return heat indices (SHI/RHI) and return temperature indices (RTI) are used as measureable performance parameters of data center.

2. Physical model

A raised floor data center room of dimensions 6.71 m × 5.49 m × 3.0 m is considered as the physical models of the present study. The data center houses 14 servers racks, each dissipating power of 3.5 kW. The racks are arranged in two rows with a spacing 1.22 m between the two rows. The racks rows are arranged to be at 1.22 m distance from the room wall. Typical raised floor plenum of depth 0.6 m and perforated tiles of size 0.6 m × 0.6 m with an opening ratio of 25% are used for the analyses. Fourteen perforated tiles are used in the cold aisle to provide