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Preliminary Analysis of Energy Efficiency in Data Center: Case Study

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***Abstract*—**As the data-driven economy is growing faster than ever and the demand for energy is being spurred, we are facing unprecedented challenges of improving energy efficiency in data centers. Effectively maximizing energy efficiency or minimising the cooling energy demand is becoming pervasive for data centers. This paper investigates overall energy consumption and the energy efficiency of cooling system for a data center in Finland as a case study. The power, cooling and energy consumption characteristics and operation condition of facilities are examined and analysed. Potential energy and cooling saving opportunities are identified and further suggestions for improving the performance of cooling system are put forward. Results are presented as a comprehensive evaluation of both the energy performance and good practices of energy efficient cooling operations for the data center. Utilization of an energy recovery concept for cooling system is proposed. The conclusion we can draw is that even though the analysed data center demonstrated relatively high energy efficiency, based on its power usage effectiveness value, there is still a significant potential for energy saving from its cooling systems.

***Keywords*—**Data center, case study, cooling system, energy efficiency.

I. INTRODUCTION

ENERGY efficiency has always been the prime consideration for data centers. Data centers can be more than 40 times as energy intensive as conventional office buildings because of the high power requirements for the computers and the cooling system. Given the fact that the trends and technologies of consolidation, blade centers and high-performance servers have driven escalating power requirements in modern data centers, reducing the energy consumption, while simultaneously decreasing the carbon footprint, is critical to minimizing the impact of data centers to the environment and energy costs. Since cooling accounts for a large portion of those energy costs, consuming about 25% or more of the total data center power [1], increasing cooling system efficiency is the key to energy efficient data centers. Cooling systems can be generally divided into two categories: air-forced cooling and liquid cooling [2]. Air-forced cooling is the predominant and most common system to date. It consists of Computer Room Air Conditioner (CRAC) units and the associated air distribution systems for cooling the IT equipment inside racks [3]. In a large data center, a Computer Room Air Handling (CRAH) unit may be used. Any air distribution network includes a supply system and a return system. The supply system delivers conditioned air from CRAC to racks, and return system takes the exhaust air from racks to CRAC. The main distinguishing characteristics among the cooling capacities lie in the associated air distribution systems which can be further divided into three categories based on the types of air distribution networks: open system, partially closed system and fully closed system. Fully closed system is the most efficient and expensive system. Open system is the least efficient one, yet most current data centers have adopted this system due to cost concerns.Liquid cooling refers to a system where the racks contain internal liquid loops, which internally cool the IT equipment, and then pass the heat to the IT environment via liquid-to-liquid heat exchangers. Liquid cooling is a solution for large data centers, as many centers are running out of places to house the CRAC units. Very often, liquid cooling coexists with air-forced cooling and stand-alone liquid cooling systems are not very common due to cost concerns today. Air conditioning equipment types are generally grouped into five broad categories for the CRAC units. Currently, controlling CRACs is often based on sensing the return air temperature, for example, 20°C [4]. This operation model tends to be overly conservative and inefficient. Consequently, for example, many current air-forced cooling systems use maximum fan speed setting which is obviously not an efficient setup and could lead to over-ventilation for racks. In addition, cold air from CRAC units is distributed uniformly without considering the actual heat load of individual racks. The recognition of the vital role and the important potential of cooling systems in achieving the data centers' energy saving targets has encouraged us to explore new perspectives and methods aimed at increasing the energy efficiency of cooling systems. As preliminary assessment can help identify the presence of energy efficiency problems, we used case study approach to both provide more detailed perspectives of the current cooling problems and exploit the potential for energy efficiency in a data center in Finland.

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II. THE CASE STUDY

The selected data center is located in Helsinki metropolitan area in Finland, which is administered by government organisations. The main function of the data center is to provide IT support and resources. The data center has two rooms separated by a control room. As energy usage in these two room doesn't differ much, so we present the results for one room only. Fig. 1 displays the floor plan and layout of the selected room. The floor area and the room volume are 73.9 m^2 and 229.1 m^3. The room has a raised floor comprising of 26 perforated floor tiles. The dimension for each floor tile is 600 x 600 mm. The height of the raised floor surface is 600 mm from the floor slab. The open area of the perforated tiles is about 26%.

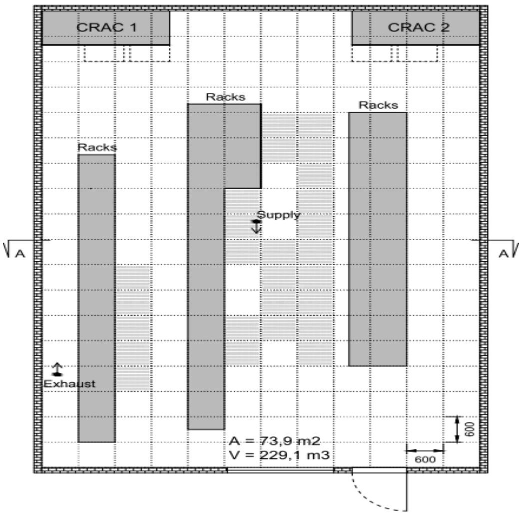

Fig.1 Floor plan and layout of the study data center. The pointed arrows denote approximate locations of the supply and exhaust ventilation ducts

The basic physical characteristics of the data center are summarised below:

A. Room Envelopes

Brick for the interior walls with thickness 130 mm: The intermediate floor structures are cavity slabs (265 mm). The base floor consists of ground slab (100 mm), expanded polystyrene (50 mm) and gravel (200 mm).

B. CRACs

Three rows of racks with servers and other IT hardware: The degrees of actual densities among racks vary. The power consumption of the IT-equipment per rack ranges from a few kilowatts to a maximum of 20 kW with full racks. In addition to conventional air-cooled racks, there is one liquid cooled rack with a rated maximum power consumption of 2 kW.

C. Cooling System

Air-forced cooling system: CRACs and IT equipment racks form open system with locally ducted supply and flooded return; Air conditioning systems: chilled water system with free cooling mode which is activated when the outside air temperature is below 5°C. CRACs (two units) with capacity rated cooling power 47 kW and air flow rate 4.3 m^3/s per unit. Chiller (cooling circuit): capacity 109 kW; Pump (cooling circuit): capacity 4 kW, water flow rate 5.64 dm^3/s; Pump (cooling circuit, free cooling): 3 kW, fluid flow rate 5.86 dm^3/s; Fluid coolers: capacity 140 kW, fan power 4 x 0.55 kW, 35% ethyl. glycol, fluid flow rate 5.86 dm^3/s, air flow rate 18.2 m^3/s.

III. Measurements And Results

We focus on temperature measures in this paper because our aim was to analyse energy consumption of the data center and efficiency of the cooling system. The supply and return air temperatures were monitored continuously from the two racks (CRAC1 and CRAC2). The readings of rack inlet and exhaust air temperature were taken at the centerline of the rack at about 1.2 m from floor level. The room supply and exhaust air was measured from the ventilation duct openings for another room. For some reasons, the facility and IT power consumption data were not provided by the data center. However, we shall estimate the values based on all available measurement data. Fig. 2 and Fig. 3 present the temperature measurement patterns for CRAC1 and CRAC2. The measured rack inlet and exhaust air temperatures are displayed in Fig. 4. The room supply and exhaust air temperatures, measured from the ventilation duct, are presented in Fig. 5. The Measured temperatures at the center of the perforated floor tiles in the data center are shown in Fig. 6.

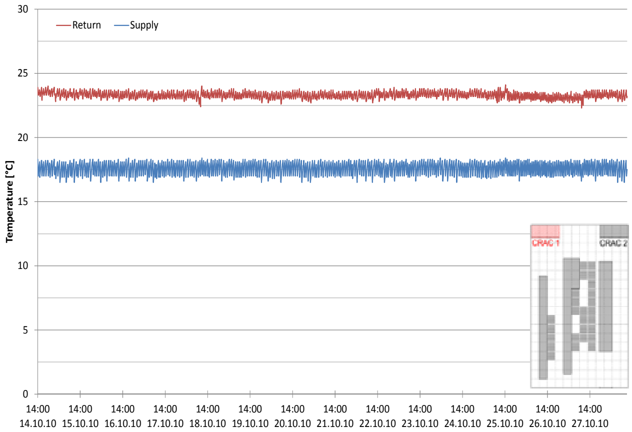

Fig. 2 Measured return and supply air temperatures for CRAC1; The values are averages of two measurement points

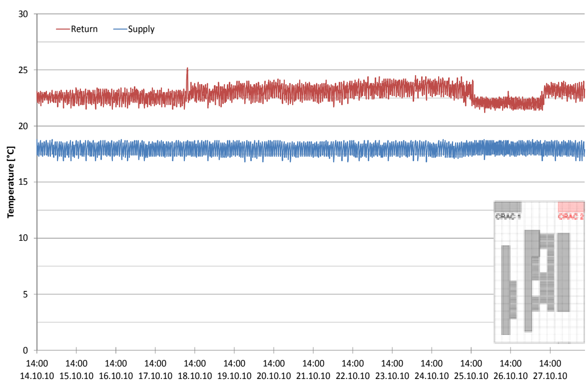

Fig. 3 Measured return and supply air temperatures for CRAC2; The values are averages of two measurement points

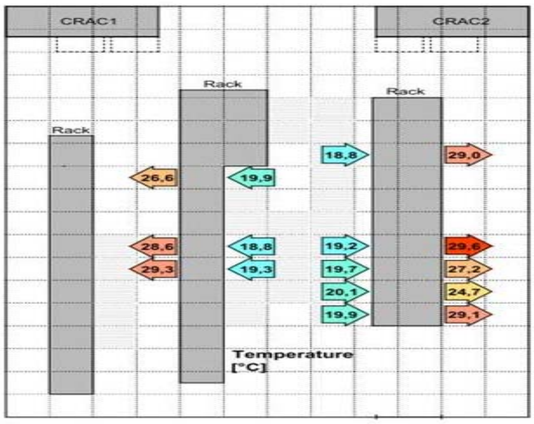

Fig. 4 Measured rack inlet and exhaust air temperatures; The readings were taken from the center axis of the racks about 1.2 m from the floor level

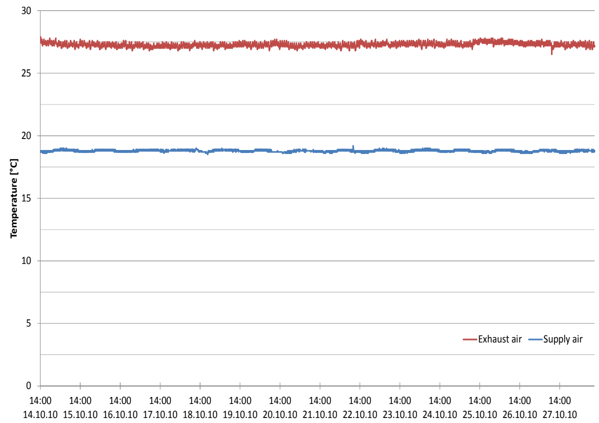

Fig. 5 Measured room supply and exhaust air temperatures from the ventilation duct openings

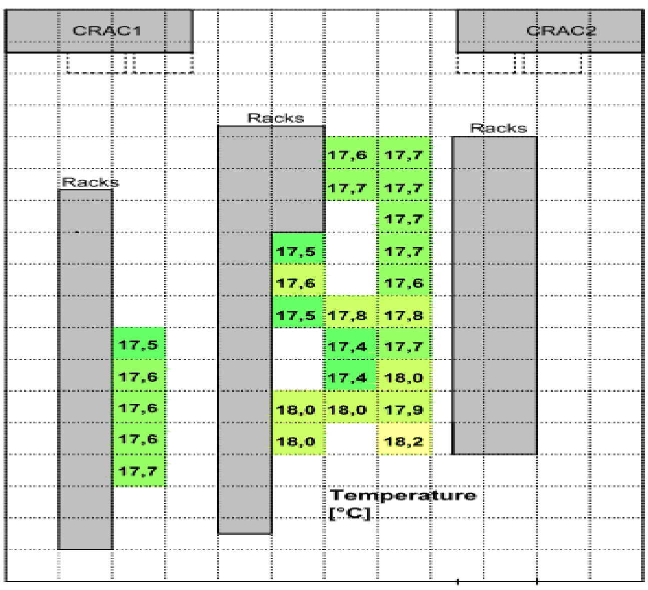

Fig. 6 Measured temperatures at the centers of the perforated floor tiles

IV. ANALYSIS

D. CRAC Cooling Power

Fig. 7 presents the calculated cooling power of CRAC1 and CRAC2 based on the measurements shown in Fig. 2 and Fig. 3. The total CRAC cooling power was estimated at 57.2 kW based on the average temperature differences obtained from the building automation systems for the running two CRACs.

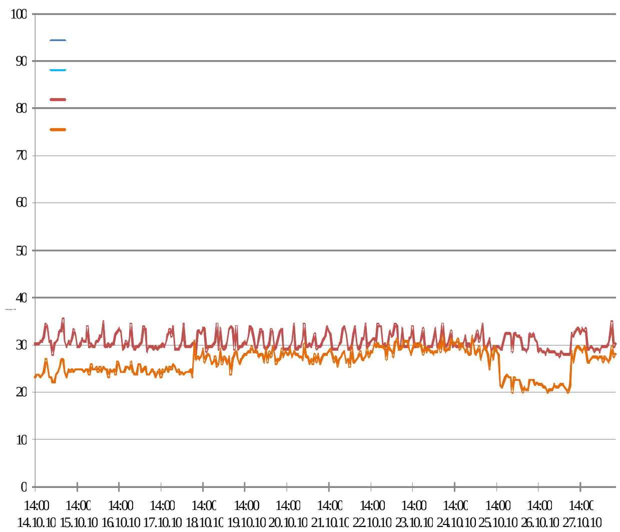

Fig. 7 Calculated cooling power of CRAC1 and CRAC2

E. CRAC Inlet Conditions

The measured rack inlet temperatures were in a range of 19 – 20 °C, see Fig. 3. These values fall within the recommended ASHRAE range [5] of 18 – 27 °C for rack inlet temperatures. However, the values were at the low end of the range. A higher efficiency and higher temperature set than 19 – 20 °C could be obtained.

F. Air Exchange Rate

The volumes the data center is 229 m^3 with the design value of the exhaust air flow rate of 0.05 m^3/s which gives the air exchange rate as 0.8 1/h. This is much higher than the rate, 0.25, recommended by ASHRAE [2]. The ventilation rate should be minimized in order to both save the energy and decrease the humidification and dehumidification load.

G. Performance Metrics

The performance of the cooling system in data center was evaluated by calculating the Supply Heat Index (SHI) [6] and Return Temperature Index (RTI) [7]. Index SHI is used to indicate how much the hot and cold air mix up, whilst RTI measures the levels of recirculation air and bypass air. All the calculated SHI-values were less than 0.4, which indicated little or no recirculation air. There were, however, differences between the individual SHI-values indicating that supply air wasn't properly supplied and distributed and by-pass air may have existed. The index RTI of the cooling system was calculated as RTI = 0.53, suggesting a large portion of bypass air.

H.Power Usage Effectiveness

Power Usage Effectiveness, PUE, is one of the most commonly used metric for describing the energy efficiency of a data center. PUE is defined as the ratio of IT load power to data center input power (facility power). Based on all available measurement data, the estimated PUE for the data center was about 1.2 during winter and 1.7 during summer on average, indicating high energy efficiency. The PUE difference between summer and winter is due to the free cooling, which improves the energy efficiency.

I. Energy Recovery Potential

To evaluate the potential for energy recovery the measured and calculated data are used here. Previously, we analysed the total cooling power from CRACs, which was about 57.2 kW on average. Assuming a COP of 3.0, then the compressor power becomes

57.2 kW / 3.0 = 19.1 Kw

The heat energy reuse potential equals the total cooling power plus the compressor electrical power which gives

57.2 kW + 19.1 kW = 76.3 kW.

Assuming a cost of 0.07 €/kWh for electricity, then the yearly potential reuse condensate energy will be 668.4 MWh which leads to 46788 € potential savings if electricity is used for heating.

V.CONCLUSION

This paper presents a case study on overall energy consumption and energy efficiency of cool system for a data center in Finland. The potential for energy recovery is also explored. The results show that even though the data center demonstrated relatively high energy efficiency, based on its PUE value, there is still energy saving potential. The studies reveal a number of options for energy efficiency, for example increasing required supply temperatures for racks at the examination area, decreasing the ventilation rates and setting a higher chilled water temperature, among many others. Calculations also show that the potential for energy recovery is substantial. The yearly energy recovery saving in cooling system about 668.4 MWh or 46788 €, which could increase due to increasing electricity rates.

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