Study of a data center and creation of its numerical model

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Abstract— Modern data centers are huge consumers of energy worldwide which require particular attention as to reducing their energy consumption and improving their energy efficiency. A data center has been examined and necessary measurements were made. For this purpose the characteristics of a data center such as the thermal load of datacom equipment and from other sources were determined, the air flow and air temperature in the data center were measured, as well as other parameters that are required to obtain a full picture of the data center.A numerical model of this data center was created and a software package PHOENICS was used. To simulate of a data center by using analysis the most appropriate size and numerical network model of turbulence were selected. By simulating a numerical model the temperature field, field of pressure and air velocity in the data center and the ability to perform additional tests using the given model were obtained and a more detailed picture of the current state of the data center was gotten. The numerical model of the data center is evaluated by comparing the results from the simulations of the model and the measurements done, as well as by means of energy balance, so that it can be used to optimize the data center.

Index Terms— data center, datacom equipment, simulation, numerical model, load

1 Introduction

THE data centers are standardized into 4 classes according to the regulated parameters of air (dew point, temperature and relative humidity of the air) which are required for proper operation of the datacom equipment [1]. Maintaining the working conditions of datacom equipment is a major precondition for its smooth running 24 hours, seven days a week, thus resulting in threefold increase of the working hours compared to other official buildings. From that point, every minimizing of the costs and increasing the energy efficiency of data centers is of essential value.

2 Description of the Actual State of the Subject Data Center

The tested data center has dimensions 14.2 m x 25 m, i.e. an area of 355 m^2. The heat dissipation from the datacom equipment, which is set upon a raised floor in the center is in accordance with the recommended layout of cold/hot aisles, and it amounts to 462.3 kW. For the purpose of further analysis, datacom equipment is tagged and its place in the designed plan of the room is located. The center includes datacom equipment of every kind, with loads ranging from 2 kW up to 20 kW. The cooling load from the external sources is 21.3 kW, and the one from the lighting runs up to 5.33 kW.

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The average heat load is focused upon the area of the room which is 1377.3 W/m^2, whereas the heat density in the room is not being uniform. The air-conditioning of the center uses six cooling units (one of which is a reserve) with a total air flow of 108000 m^3/h. They bring in an air having a temperature of 13°C into the raised floor, whose height is 0.5 m. For supplying the conditioned air into the room perforated plates sized 0.5m x 0.5 m which are placed in the raised floor of the room are being used. Extracting the return air from the room is done through exhaust barred opening placed near the ceiling, which are connected to the plenum by ducts located above the cooling units.

2.1.1 Measurement of the air flow

For the purpose of air-conditioning of the center, cooling units supplying cold air into the raised floor of the data center are being used, the said air entering the room through the perforated plates within the raised floor, thus shaping the cold aisles.

First, the layout of the perforated plates in the raised floor is determined, the plates are tagged, and measurements of the air flow through each of the 60 perforated plates is being carried out individually with the measured values shown in Fig.1. The total air flow through all controlled openings (perforated plates) is 99 700 m^3/h. The air flow through the uncontrolled openings (between perforated plates etc.), is taken into account as an approximate immeasurable air flow which according to [4], [7], amounts to 16.8 (m^3/h)/ m^2, meaning that in the particular center it runs up to 5964 m3/h. The difference between the designed air flow through the air-conditioning equipment and the measured air flow in the data center is due to undesired leaking of the air along the perimeter of raised floor as well through the cable opening.

The air flow from the individual cooling units flowing into the raised floor due to its unsteadiness and turbulence makes the measurement a complex task. The multiple measurements in each individual cooling unit were averaged, and each cooling unit showed difference relative to the designed air flow due to the different pressures within the raised floor.

2.1.2 Measurements of the air temperature

To determine whether an appropriate cooling is supplied to the datacom equipment, it is vital to determine the temperatures of the air entering the datacom equipment. Also of great importance is to determine the temperature of the return air to the cooling units, indicating whether an appropriate cooling is still being supplied to the datacom equipment.

The temperatures of the supplied air at the bottom inlet to the datacom equipment, as well as at a height of 1750 mm, 50 mm in front of the equipment were measured in accordance with the recommendations [1], [4], [9]. The temperature differences between the supplied air to the datacom equipment at the level of the floor and the air flow to the datacom equipment at a height of 1750 mm are shown in Fig.2.

The temperatures of the return air to the air- conditioning equipment cannot be easily measured due to the return channel extensions. Therefore the data recorded by the sensors of air conditioning equipment were being used. Their values which were manifold recorded, have been afterwards averaged within the range of 26 - 31°C. A comparison of the calculated values with values obtained by several measurements using a thermometer has been made. The difference in temperature measured by sensors in the cooling units and by a thermometer is negligible one.

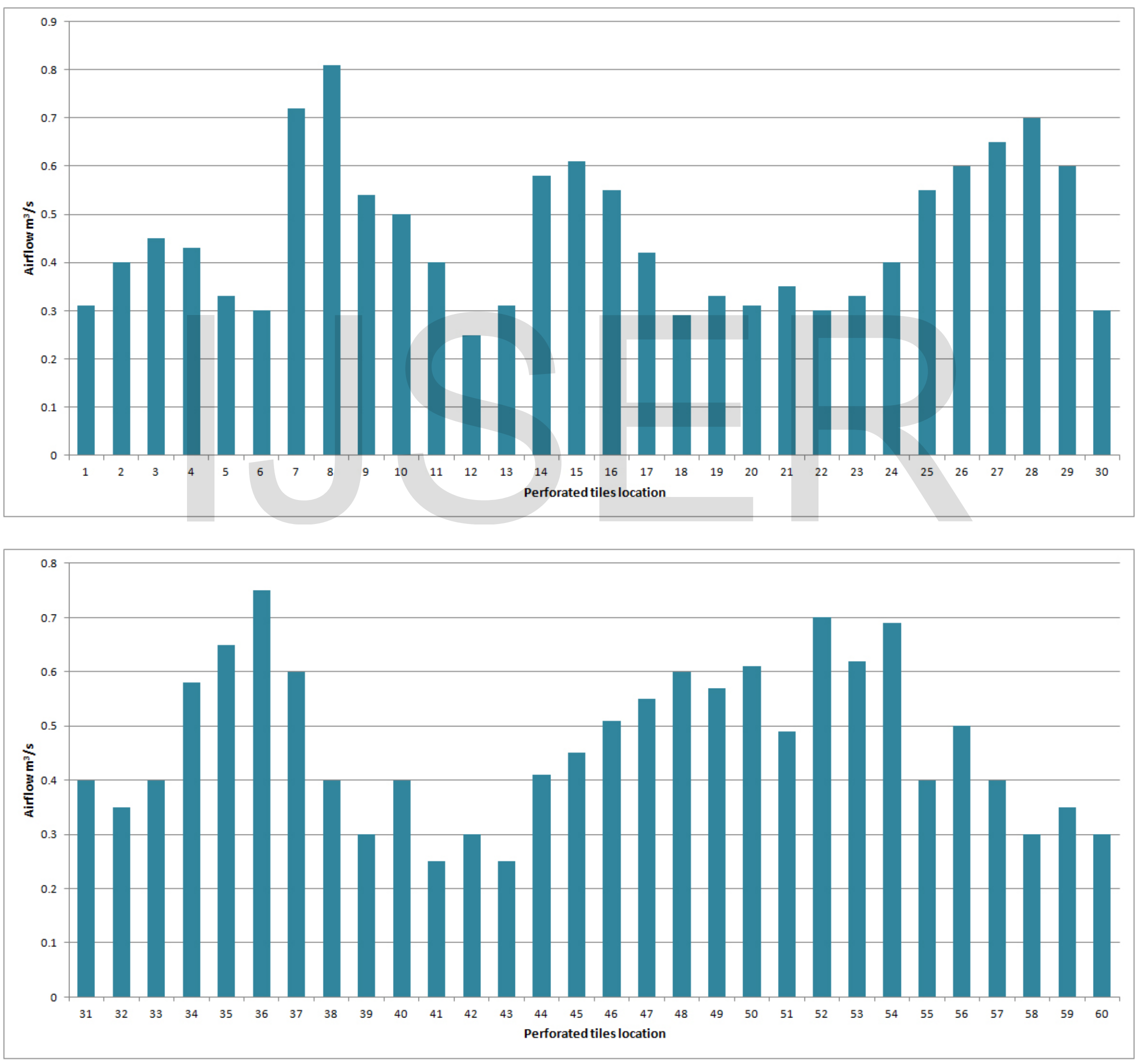

Fig. 1 Airflow through the perforated tiles into data centre

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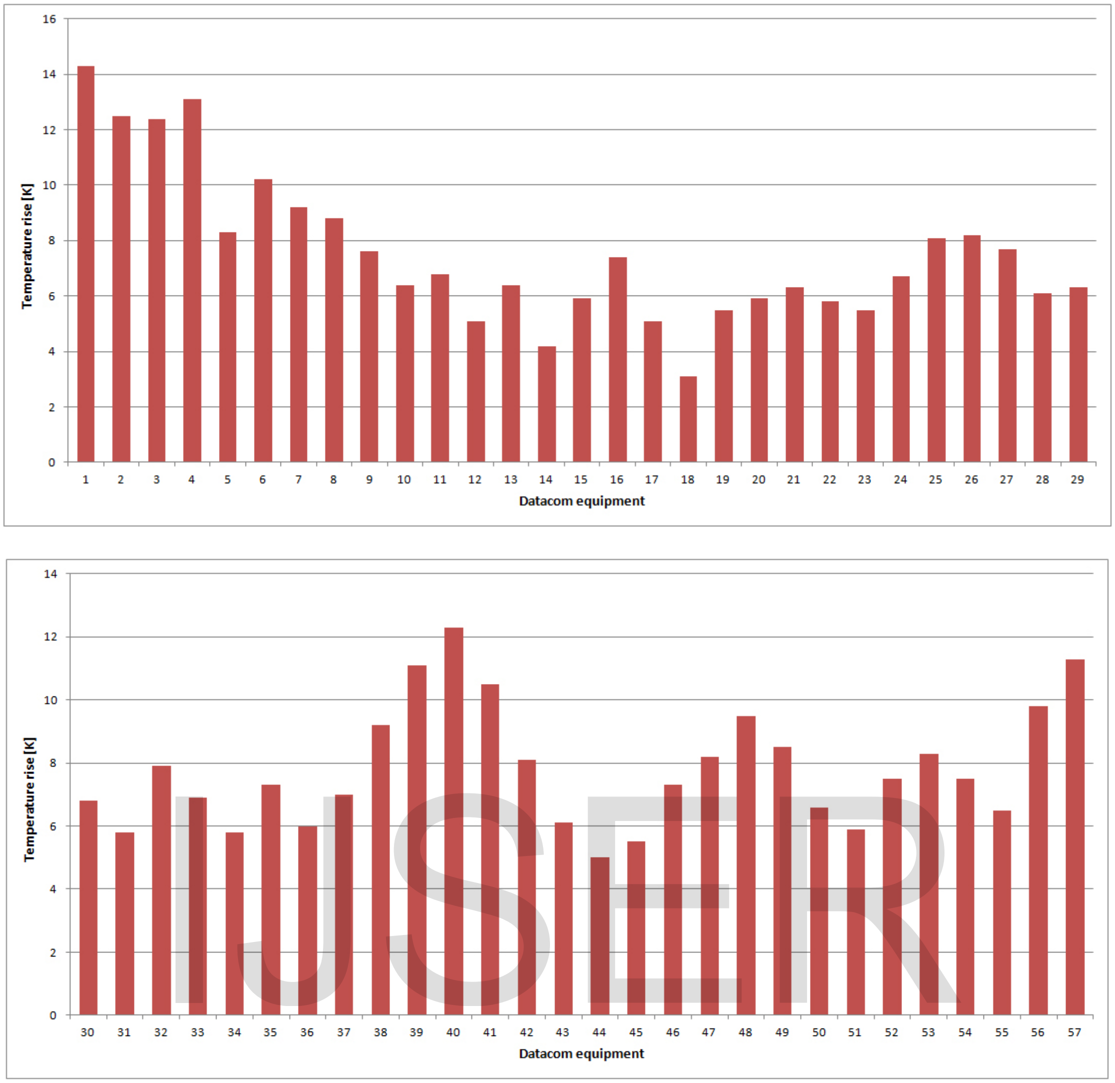

Fig. 2 Temperature rise to inlet of rack

2.1.3 Analysis of the results of the measurements in the data center

The analysis of the measurements leads to the conclusion that generally percieved, the datacom equipment operates within the designed conditions. Although the datacom equipment is deployed in the recommended schedule hot/cold aisle, there is a recirculation of hot air to datacom equipment, which is especially pronounced at the ends of aisles and the upper parts of the equipment. The distances between the datacom equipment, to wit the small width of the aisles cause to direct the hot air towards the adjacent cold aisles and its being sucked into the datacom equipment.

The overview of areas in this study allows the conclusion that there are areas with higher heat density and lesser heat density than average one. The cooling system is designed for the average heat density, yet it has the ability to cool areas with a heat density greater than the average one.

Figure 2 shows that the temperatures of the air at the inlets to the datacom equipment are within the design limits, but in parts of the datacom equipment marked with the numbers 1, 2, 3, 4, 6, 7, 25, 26, 27, 38, 39, 40, 41, 42, 47, 48, 56 and 57 the temperature increase is substantial. The main reasons for the rise of the temperatures are the improper distribution of cold air through the perforated tiles, the recirculation of hot exhaust air from datacom equipment towards the inlets to the equipment and the proximity of datacom equipment to the coolin units. The distribution of cold air through the perforated tiles is determined by the static pressure of the air and theairflow within the raised floor, and is influenced by the great space above the floor.

The carried out analysis allow the conclusion that there are possibilities to optimize the working conditions of the data center by optimizing the layout of datacom equipment and perforated tiles, whereas it is especially important to optimize the flow of the supplied cold air and the exhaust warm air.

3 Simulation of the Data Center

The simulation of the data center used the program package PHOENICS, which is an acronym for Parabolic Hyperbolic Or Eliptic Numerical Integration Code Series. It is based on the method of finite volumes in order to discretizate of the transport equations, and is the first software of this kind.

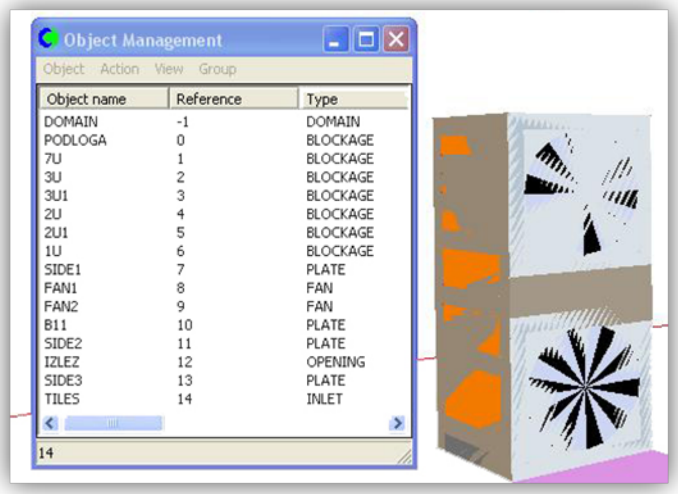

Fig. 3 Model of datacom equipment in PHOENICS

The collected data (measured and determined) for the data center are used for PHOENICS CFD model of the data center. The created center represents an image of the real data center. First, numerical models of the datacom equipment (racks) with dimensions and heat dissipations identical to the actual equipments installed in the center are created (Fig.3) [2]. [5], [9]. The geometry of the datacom equipment undergoing these specific measurements is replicated in these computer models. The dimensions of the data center, the layout and heat dissipation of datacom are being modeled. The layout of the perforated plates in the floor of the room, as well as the air temperature and the velocity of the air flow through them are also included in the model. Modeling of the inlets and outlets for the air and the other components is based on the real situation in the existing data center.

To simulate the center, in this case the Cartesian 3D network is used having a domain equal to the reference center. The impact of selected numerical grid upon the results of the simulation is examined. Tests showed that the generated network of the simulation is good if the cells have a square cross section with side 10 cm, but the independence of the design from the size of the numerical grid is achieved for the cell square of side 5 cm. During the simulation of the data center four different models of turbulence were used, such as: standard $k-\varepsilon$, RNG $k-\varepsilon$, Chen-Kim $k-\varepsilon$ and $k-\varepsilon$ - TSKE, all models showing good match to the tested parameters of the model with the measured values in the data center. The standard $k-\varepsilon$ and Chen-Kim $k-\varepsilon$ are bringing the model closest to real data center.

By means of CFD using the standard $k-\varepsilon$ turbulence model, the temperature field, the field of pressure and the velocity for the entire data center are being obtained. Their analysis yields a detailed picture of the tested magnitudes at each point of the data center.

Fig. 4 shows the airflow in the data center by means of the velocity field. Using the CFD results the air velocity in any given part of the center, that is, in the vicinity of the datacom equipment, through the perforated tales and near exhaust openings, can be analyzed.

The temperature field obtained by simulation using the standard $k-\varepsilon$ model of turbulence is shown on Fig.5. By means of the temperature field an insight into the temperatures of the air entering the datacom equipment, the air in the hot / cold aisles, and the air near the exhaust openings can be gained, and thus to specify the point with high temperatures.

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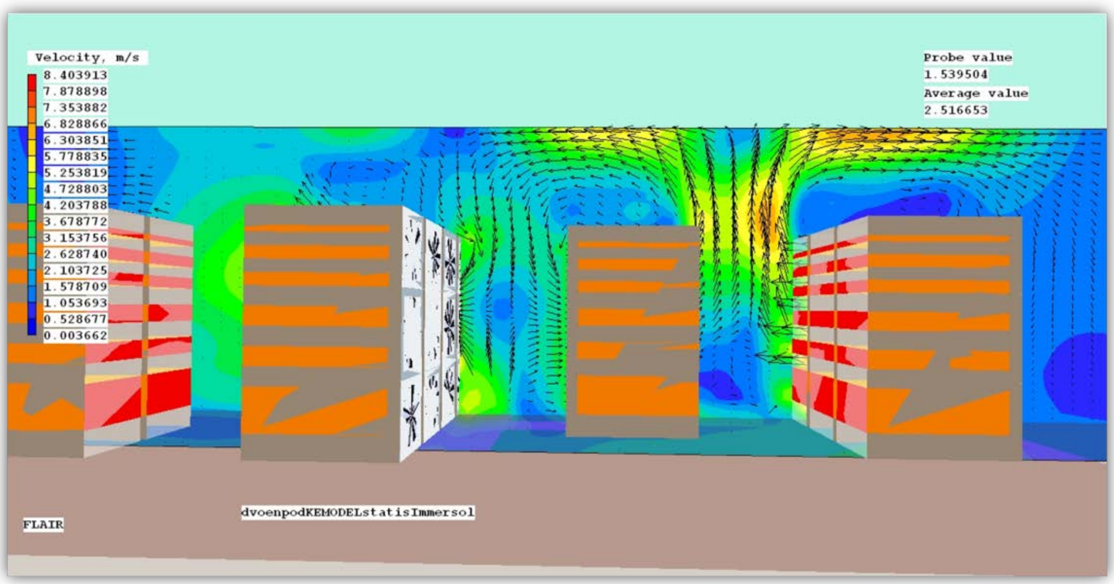

Fig. 4 Velocity profile within the data center, air recirculation between datacom equipment marked with no. 3 and 14 (standard $k-\varepsilon$ model)

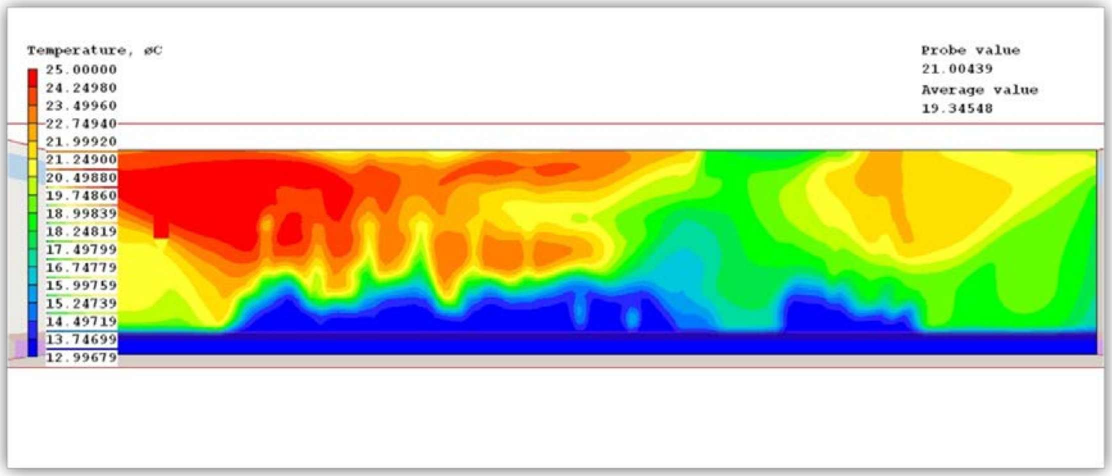

Fig. 5 Temperature field in the data center section parallel to the plane xOz - 50mm before datacom equipment, y = 2,75m, (standard $k-\varepsilon$ model)

4 Conclusion

The analysis of the measurements showed that datacom equipment is operational within the designed conditions, albeit there are possibilities to achieve them at a lower energy cost, if certain weaknesses detected in the examination of the data center are overcome.

The first step in the serious analysis of the energy efficiency of the data center is to determine the existing energy consumption.

The recirculation and mixing of the exhaust heated air and the supplied cold air, which takes place in the tested center, makes it difficult to achieve the recommended conditions for the operation of the datacom equipment. One way to achieve this aim is to physically separate the hot and cold air in the data center and to minimize their interference, using double ceiling as a space for disposing of the hot air and bringing in the air back into the cooling units, or by placing barriers within the cold corridors. This will help to meet the designed requirements of the data center by achieving a temperature of the supplied cold air below 13 ° C.

There are areas within the center with much higher heat load than the average one. To achieve adequate cooling of the equipment with greater heat dissipation, it is necessary to set a new layout of the equipment, by locating it at points having the highest static pressure of the air within the raised floor.

This paper employs direct measurements of the thermal load, air flow and air temperatures as well as other necessary parameters in the data center to create a numerical model of the data center. The obtained simulations allow achieving a full insight into the overall situation in the center identifies the shortcomings and enables further investigations using a CFD model of the data center. The model of the data center provides an opportunity for an accurate assessment of the temperature fields, air velocities and pressures, and may be considered an useful tool for further investigation in order to improve the energy efficiency of the data center.

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