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An Evaluation of Data Centre Energy Efficiency

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***Abstract:-* The increasing use of Information Technology, has resulted in an increase in the demand and use of internet facilities. This resulted in the increased size of data centres which led to an increase in energy consumption. This study focuses on improving the airflow within a virtual data centre. The computation fluid dynamics simulation will be used to evaluate the airflow and temperature performance of the virtual data centre. An improved airflow ensures that the data centre is cooled efficiently and air recirculation is avoided and eliminated. This would enable the proper channelling of airflow within the data centre with a view to avoiding mixing up of the hot air generated from the operating equipment and the cold air used to cool and maintain a good temperature for the operating equipment to function well. The power usage effectiveness and the airflow performance index will be evaluated using their matrices to determine the performance of the virtual data centre.**

Key words:- Data centre, energy efficiency, power usage effectiveness, data centre infrastructure efficiency, airflow performance index.

1. INTRODUCTION

A data centre is a server or computer room, where the majority of an enterprise server and storage are operated, located and managed [1]. Data centres are facilities hosting a larger number of servers dedicated to massive computation and storage. They can be used for several purposes, such as interactive computation (e.g. web browsing), batch computation (e.g. rendering of images and sequences) and so many others.

Data centres can be seen as a composition of [2]:

1. Information technology (IT) systems: The information technology systems provide service to the end users. The information technology systems include servers, storage and network devices, middle wares and software stacks, such as hypervisors, operating systems and applications.
2. A support infrastructure (also known as non-Information Technology systems): this supports the Information technology system by supplying power and cooling. The support infrastructure such as the back-up power, generators, uninterrupted power supply (UPS), power distribution units (PDUs), batteries and power supply units that generate and distributes power to the individual Information Technology system. The cooling technology (CT) system includes server fans, computer room air conditioners (CRACs), chillers, and cooling towers. They generate and deliver the cooling capacity to the information technology systems.

The information technology systems consume power and generate heat whenever they are on. The Cooling technology systems extract the heat to maintain the thermal requirement of the information technology devices in terms of temperature and humidity. The information technology, power and cooling control system have to work together to manage the resources, power and cooling supply and demand [2]. Figure 1 shows a data centre model.

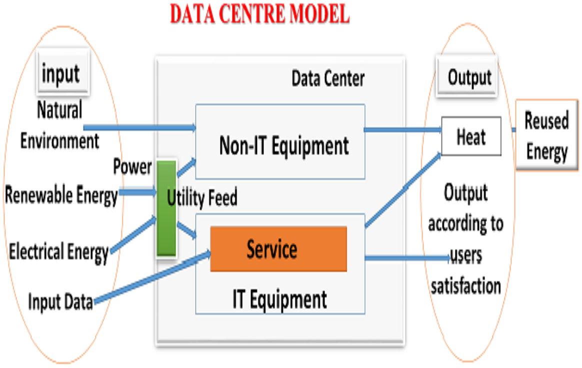

Figure 1: A Data Centre Model [3].

A study made by US energy department shows the detailed energy use within the data centre. It was noticed that 45% of energy is consumed by cooling device, 10% is consumed by power conversion and distribution units, only 45% was really spent on actual information technology (IT) device as shown in Figure 2. On information technology devices only 30% of the power is spent on processor, the other 70% is spent on peripheral components including power supply, fans, memory, and disk. Even the power used by the processor is not fully utilised. The average processor utilisation is always below 20% which implies that most of the time, the server is idle [4].

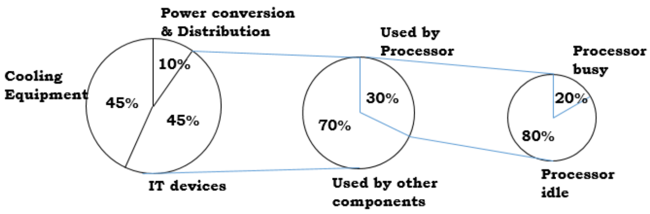

Figure 2: Data Centre Energy Use Breakdown [4].

Energy efficiency refers to the behaviour or act that results in the use of less power. It is achieved by using different techniques and methods that require less power to perform the same task. The excessive use of power in data centre has placed unnecessary load on local utilities and caused environmental concerns for pollution and ecological stewardship [5].

The development and implementation of energy efficient resource management strategies in data centres has become a prequisite to implement energy efficient, green and environment-friendly data centre. The actual energy consumed by the data centre does not affect the cost of infrastructure, but is reflected in the electricity cost consumed by the system during the period of operation [5].

Energy efficiency has become a significant metrics that is progressively implemented to evaluate and measure the energy utilization of device installed in data centre. Energy efficiency metrics and benchmarks are used to track the performance of a data centre in power and energy use at different levels [5]. The green grid defined the power usage effectiveness (PUE) and data centre infrastructure efficiency (DCiE) metrics as useful methods of understanding the energy usage within the data centre. The power usage effectiveness and data centre infrastructure metrics enables a data centre operator to estimate the energy efficiency of their data centre, compare the results against other data centres and determine if any energy efficiency improvements needs to be made [6].

2. REVIEW OF KEY CONCEPTS

Virtualisation is one of the methods that can be used to overcome the energy problems of data centres. Virtualisation is a mechanism that saves a huge amount of energy and at the same time increase productivity of servers with little or no additional energy consumption. Decision on server virtualisation is based on categorisation done by server consolidation has categorised servers into three resource pools which are: innovation, production and mission critical servers depending on their workload and usage. This process aids a reduction in the numbers of physical servers by consolidating the load of multiple servers on one server. It can be noted that decreasing the number of physical servers does not only reduce energy but it also has a great impact on the overall heating requirement, cooling load as well as the Uninterrupted power supply (UPS) backup time of the data centre. [7]

Using the principle of air management to evaluate the energy performance of the cooling systems within a data centre is also another method of checking energy consumption. Data centres built with a raised floor and racks arranged in hot aisle and cold aisle layout is one of the best methods thus far of implementing air management. The data centre having a fluid-side economizer with the chilled water system is a source of free cooling. The average power usage effectiveness for such data centres is slightly above 1.2 in winter and 1.5 in summer. The difference is likely caused by the free cooling which was activated when the outside temperature was below 8ºC. [8]

The performance of an airflow simulation within an internet data centre facility can be evaluated using the computational fluid dynamics. The computational fluid dynamics is a scientific technique that can be applied to improve the data centre performance without interfering with the function of the data centre. This aids in checking the airflow, cooling approach and temperature within the data centre. [9]

Another method is the energy efficiency management process in a data centre. This outlines four methods that can be pursued to increasing energy efficiency in data centres. The methods are[10]: increasing the efficiency of the information technology usage, facility efficiency, the use of renewable energy and information technology efficiency. To increase the energy efficiency of information technology usage, servers in the data centre should be used at 100% workload. This step can be accomplished when server virtualisation techniques and consolidation are employed. Facility efficiency deals with avoiding waste of energy and using more efficient cooling system to cool the facility. The use of renewable energy source such as photovoltaic energy, wind energy, hydropower energy will improve the energy efficiency of the data centre. [9]

Improving energy efficiency via optimizing the airflow within a server room can lead to a more efficient cooling circuit. Airflow optimization involves the separation of airflows-housing, experienced based placement and simulation. The separation of airflow was done to avoid recirculation and reduce the overall cooling requirement. Experience-based placement means placing systems based on experience and physical parameters like blower direction. [11].

2.1 Data Centre and Efficient Energy Usage

Information Technology has become an integral part of a man’s day-to-day activities. The need for information is rapidly increasing among all groups of people. This increase in the use of Information Technology has caused an increase in the demand and use of the internet facilities. For network providers to be able to meet up with the demand, there has been a rapid increase in the size of the data centre which in turn resulted in an increase in demand for energy. As a result, there is an urgent need to make a more efficient and reliable energy consumption system. This can be done by reviewing the energy consumption of the various systems that make up the data centre such as: server virtualisation, minimizing the energy losses, seeking for a more advanced way of cooling the system with less cost and less energy dissipation and so on.

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3. METHODS/DISCUSION

A virtual data centre will be modelled and simulated to evaluate the energy performance of the centre using an improved airflow system. Metrics will be applied to evaluate the performance of the data centre. The improved airflow system will be analysed using the computational fluid dynamics.

3.1 Power Usage Effectiveness (PUE)

The Power Usage Effectiveness is defined as a ratio of total data centre energy use to Information Technology device energy use. The power usage effectiveness is a common metric that accounts for the electricity use of the infrastructure equipment [10]. The Power Usage Effectiveness indicates how much power is used by the facility infrastructure to power and cool the Information Technology equipment and to power the redundant distribution system required for maintaining the expected availability and reliability of the information factory services [3].

$$\text{PUE} = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}} \qquad (3.1)$$

1. Information Technology Equipment Power: The Information technology (IT) equipment power is defined as the equipment that is used to manage, process, store or route data within the raised floor space in the Data Centre [13]. It includes all the load associated with the Information Technology devices like servers, storage equipment, network equipment, computer and the supplementary equipment such as switches, monitors laptops/workstation used to monitor or otherwise control the Data Centre.
2. Total power facility: It is defined as the power measured at the utility meter. This power is dedicated solely to the Data Centre [13]. It includes all the Information Technology equipment power plus everything that supports the Information Technology equipment load such as; Power delivery components like Uninterrupted Power Supply (UPS), switch gears, generators, batteries, Power Distribution Units (PDU) and so on. Cooling system equipment are the chillers, computer room air conditioning (CRAC), direct expansion air handler (DX) units, pumps and cooling towers. Other miscellaneous components such as data centre lightning and so on.

3.2 Data Centre Infrastructure Efficiency (DCiE)

Data Centre Infrastructure Efficiency matrices is defined as the ratio of Information Technology equipment power to the total facility power [14].

$$\text{DCiE} = \frac{\text{IT Equipment Power}}{\text{Total Facility Power}} \qquad (3.2)$$

3.3 Supply Heat Index and Return Heat Index

Supply heat index and Return heat index access the magnitude of recirculation and mixing of hot and cold streams. Return heat index measures the extent to which cool supply air mixes with a warm return stream. Supply heat index measures the extent to which warm return air mixes with cool supply air. The values of RHI and SHI are between o and 1. High return heat index and low supply heat index values denotes good separation of air streams [15]

3.4 Rack Cooling Index

The rack cooling index is designed to measure how effectively equipment racks are cooled and maintained within the data centre industry's thermal guidelines and standards [15]. This provides an unbiased and objective way of quantifying the quality of air management design from a thermal perspective. The required input data to be measured is limited to the information technology equipment air intake temperature [16].

3.5 Computational Fluid Dynamics

The governing equations for velocity, pressure and temperature fields are explained for 3-dimensional analysis [17].

1. Continuity equation: this describes the conversion mass in the control volume.

$$\frac{\partial \rho}{\partial t} + div(\rho \underline{U}) = 0 \qquad (3.3)$$

The momentum equations in each direction are derived from Newton's second law and it states that force is equal to acceleration times mass.

2. X-momentum equation

$$\frac{\partial(\rho u)}{\partial t} + div(\rho u \underline{U}) = -\frac{\partial p}{\partial x} + div(\mu grad\, u) + S_u \qquad (3.4)$$

3. Y-momentum equation

$$\frac{\partial(\rho v)}{\partial t} + div(\rho v \underline{U}) = -\frac{\partial p}{\partial y} + div(\mu grad\, v) + S_v \qquad (3.5)$$

4. Z-momentum equation

$$\frac{\partial(\rho w)}{\partial t} + div(\rho w \underline{U}) = -\frac{\partial p}{\partial z} + div(\mu grad\, w) + S_w \qquad (3.6)$$

5. Energy equations: this equation is derived from the first law of thermodynamics. It states that the net heat transfer into a control volume plus the net work done by the same control volume is equal to the energy difference of the control volume.

$$\rho C_p \frac{\partial T}{\partial t} + div(\rho C_p T \underline{U}) = -p\, div \underline{U} + k\, div(grad\, T) + Q \qquad (3.7)$$

Where:

$$\rho \rightarrow density\,(kg / m^3)$$

$$u \rightarrow \text{the velocity in x - direction}\,(m / s^2)$$

$$\text{v} \rightarrow \text{the velocity in y - direction}\,(m / s^2)$$

$$w \rightarrow \text{the velocity in z - direction}\,(m / s^2)$$

$$p \rightarrow \text{pressure}\,(Pa)$$

$$S_u \rightarrow \text{source term in the x - direction}$$

$$S_v \rightarrow \text{source term in the y - direction}$$

$$S_w \rightarrow \text{source term in the z - direction}$$

4. RESULTS

The modelled virtual data centre has a room size of 400m^2, raised floor height of 0.64m and false ceiling height is 3.14m. The data centre employed the hot and cold aisle arrangement. The data centre consist of 1200 information technology (IT) equipment. After the modelling, the computational fluid dynamics (CFD) analysis was carried out which gave the results of the modelled system. The total facility power was 410.7kW while the information technology power was 360kW. The result is tabulated as follows:

Total facility power	410.7kW
Information technology power	360kW
Total loss within the model	0.3kW
Percentage cooling through grilled floor	99.37%
Maximum temperature	36.8ºC
Minimum temperature	10.9 ºC
Power usage effectiveness	1.1408
Data centre infrastructure energy efficiency	87.66%
Supply heat index	0.1176
Return heat index	0.8823
Rack cooling index high	100%
Rack cooling index low	59.36%

The total loss of the entire system was about 0.3kW. The percentage cooling through the grilled floor was 99.37% while the cooling supplied is 53.1m^3/s. The minimum operating temperature of the room was 10.9ºC and the maximum was 36.8ºC. The power usage effectiveness was 1.1408. The Data Centre infrastructure energy efficiency was 0.8766 which indicates that the Data centre was 87.66% efficient.

5. CONCLUSION

Based on the evaluation carried out using a virtual data centre, it is noted that the data centre infrastructure efficiency was about 88% which shows an efficient system as compared with standards in literatures. Hence the energy efficiency within a data centre can be up to 90% or more depending on the method employed by the designers and operators to ensure an energy efficient system.

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