EFFICIENT UTILISATION OF ELECTRICAL ENERGY IN THE DATA CENTRE OF THE HS AUGSBURG BY USING SMART METERING

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ABSTRACT

Energy Efficiency is becoming an important concern in the design and management of data centres (DCs). For example, the data centres in Germany consumed 1.8 % of the total electricity consumption in 2008 [1]. Estimates also indicate that national energy consumption by servers and data centres could nearly double within five years [1, 2]. Many organizations have started looking for answers to the significant increase in power consumption in DCs. In this article, we describe the efforts taken by the University of Applied Sciences Augsburg (HS Augsburg) to make its DC more energy efficient than it is today.

INTRODUCTION

Most of the electrical power used by the IT equipment in a DC is converted into heat energy. This forces DCs to use a significant portion of their power consumption to cool down the equipment. An analysis made by the German Energy Agency [3] shows that on average 50 % of the energy consumption is caused by the IT equipment and the other half is necessary for additional equipment (cooling system: 25 %; air ventilation: 12 %; uninterruptible power supply (UPS): 10 %; light, etc.: 3 %).

These figures show clearly that besides using energy efficient hardware the energy efficient operation of the air-conditioning system is of central importance. The DC of the HS Augsburg gives rise to electrical energy costs of approx. € 27,000 per year. So a more efficient utilization of electrical energy in the DC would have a great financial impact.

The problem described was addressed in two ways: firstly, we focused on the cooling system of the DC since it has the greatest cost reducing potential in the short term. Improving the energy efficiency of the IT hardware was not taken into consideration in this paper since improvements can only be realised by changing the equipment and not by a more energy efficient operation. Secondly, intelligent electricity meters were installed to see how much energy is consumed and at what time of day in order to quantify the energy efficiency of the DC and to take further measures.

DESCRIPTION OF THE INFRASTRUCTURE

The DC of the HS Augsburg is located on the north side of the H building on the 4th floor. Apart from the staff offices in the DC, the Competence Centre Mechatronics and one lecture room are also located on this floor. On the 3rd floor there are several computer rooms for students.

Data Centre

The central server room at the HS Augsburg is 85 sqm in size. In this room 26 x86-server and one Sparc-server plus storage systems with 67 TB in total and a storage tape (2xLTO3 with 180 slots) are installed in seven racks on a raised floor (Fig. 1).

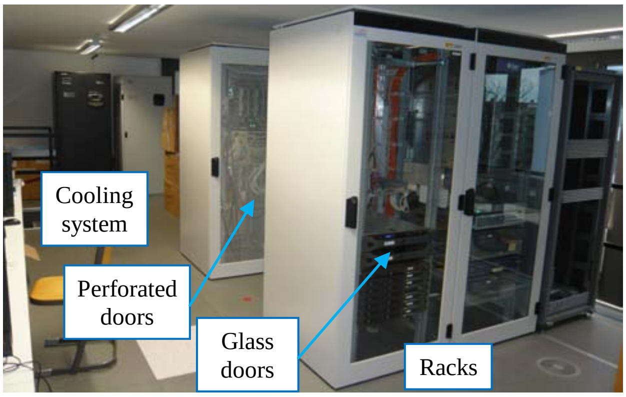

Figure 1. Picture of the data centre.

For high availability the DC is equipped with two static UPS each with 8000 VA with a permitted buffering time of 30 to 60 minutes. Additionally, each server is equipped with two redundant power supply units per device. So, in the event of the failure of a power supply unit, the remaining power supply unit is able to continue supplying the IT devices normally. One of these two power supply units is connected via UPS, the other one via the normal utility power supply network. The power supply is monitored by intelligent power outlet strips (Fig. 2).

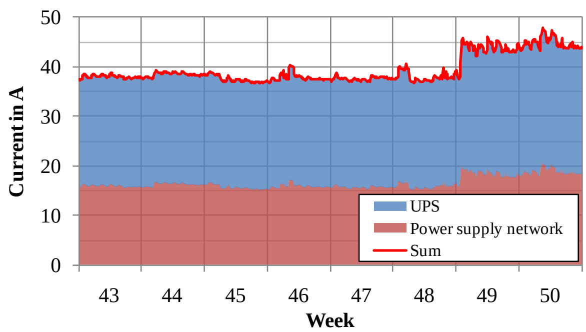

Figure 2. Total power requirement of server racks.

The current of the supply unit connected via UPS is measured after the UPS. So this value is without the charging current of the UPS. In figure 2 the effect on the electricity demand by increasing the capacity of the storage system from 31 TB to 67 TB in week 49 can be seen.

Each kilowatt of electrical power that is consumed by IT devices is released as heat. This heat must be conducted out of the device, the cabinet and the room, in order to keep the operating temperature constant. To get rid of the heat, two air-conditioning systems (AC) each with 23 kW are used. Cold supply air from the AC enters the racks directly through the raised floor in the bottom front area. Hot air leaves the rack through the perforated doors and mixes with the air in the room. Therefore, the temperature of the inlet air of the AC is not the temperature of the output air of the server racks but simply the room temperature. The systems operate in the recirculation mode, in alternating weeks.

Competence Centre Mechatronics

The Competence Centre Mechatronics (c^2m) is specialized in the analysis of fracture surfaces, phase analysis and the determination of specific mechanical material parameters. In the three labs, equipment with a connection power of 35 kW is installed. In the following the two scanning electron microscopes (SEM) are of major interest since the associated vacuum pumps (1.3 kW), the AC (2.2 kW) and the storage cabinet (1.0 kW) are operated continuously. During the summer, a second AC has to be considered. The remaining equipment is operated sporadically, when needed.

Computer rooms

The computer rooms on the 3rd floor are mainly used by students but also for some lectures. They are currently equipped with 135 PCs, 21 iMacs and 31 SunRays (thin Client) and are open during the opening hours of the DC (Mon to Thu: $7^{\underline{00}}$ to $21^{\underline{30}}$, Fri: $7^{\underline{00}}$ to $19^{\underline{30}}$, Sat: $8^{\underline{00}}$ to $12^{\underline{00}}$). The PCs are only shut down centrally after the DC is closed.

Intelligent electricity meters

The H building is supplied with electrical energy by sub-distributions located in the staircase of each floor. So each floor is divided in a north-east- and a south-west-wing (Fig. 3).

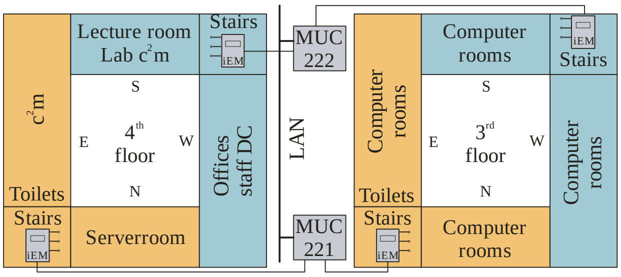

Figure 3. Overview of smart meters, MUCs (Multi Utility Communication) and wings of the H building.

Therefore, in total four intelligent electricity meters (iEM) were installed in the sub-distributions of the 3rd and 4th floor in August 2010. The meters are connected via M-bus with two MUC-controllers and with the local network. So data could be collected continuously on how much electrical energy is consumed and at what time of day/week. With the data recorded by the data logger, the behaviour of the 'consumer' (employees and students) as well as the total energy consumption of the DC was illustrated.

RESULTS

The following sections summarise the results of the investigations and recommendations for improvement are given at the end of each section.

Cooling System

The purpose of the cooling system in a DC is to meet the temperature and humidity requirements of the electronic equipment housed within the DC. Many of today's electronic switch and servers are rated for much higher operating temperatures – room temperatures of 24 to 26 °C are common practice [4] – than in the past and most have very wide humidity thresholds (40 to 80 %). Due to this wide humidity threshold this value is currently not controlled in the DC of the HS Augsburg.

In figure 4 the temperature distribution in the last year in the raised floor and at the top of the server racks are shown. It has to be considered that the raised floor is not air tight which results in a temperature difference of approx. 2 °C between the output of the AC and the entrance to the racks.

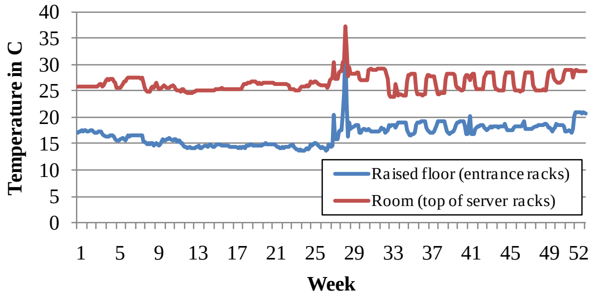

Figure 4. Temperature distribution in the server room.

In this figure four areas can be identified:

(1) Week 9 to 26: low supply air of 14.6 °C on average and 25.7 °C on average at the top of the server racks.
(2) July: Increase of the temperature of the supply air to 17 °C; breakdown of the AC and a critical temperature rise to 37 °C.
(3) August to December: Installation of AC 2 and operating in alternating weeks.
(4) Week 51 and 52: Increase of the supply air temperature to 20.8 °C without a significant change of the room temperature.

The investigations into the energy efficiency of the DC at the HS Augsburg were started in March 2010. At this time the temperature of the supply air was at a very low level – as in many other DCs. Owing to the considerations described above the temperature was raised to 17 °C in July. The breakdown of the AC in July indicated two things: firstly, the basic need for a back-up AC and secondly, the necessary time to reach critical temperature conditions.

For the safety of the IT components the temperature distribution in the server racks is important. Therefore, a thermal imaging system was used to identify hot spots and to measure the temperature at the perforated doors. These investigations have shown that the perforated sections on the server racks are suboptimal. The perforated doors have a big disadvantage with regard to the temperature distribution in the server rack. Since the airflow is totally uncontrolled and a huge amount of mixing and bypassing takes place it is necessary to have low supply air temperatures to compensate these effects and guarantee a sufficient cooling of the IT in the upper part of the racks. The leaky areas in the raised floor and in particular the possible bypassing of cold air cool down the room temperature. These effects have a great impact on the energy efficiency of the air-conditioning system.

The air-conditioning system is more efficient the higher the temperature difference between the entrance and exit of the air-conditioning. Research carried out by the Swiss Federal Office of Energy has revealed that between 22 °C and 26 °C, each degree of temperature increase will result in a 4 % energy saving [5].

In the period between August and December the cyclical temperature changes attract attention. In figure 6 and 7 the electrical energy consumption of the server room (plus c²m) and the temperature distribution in the server room during November and December are illustrated.

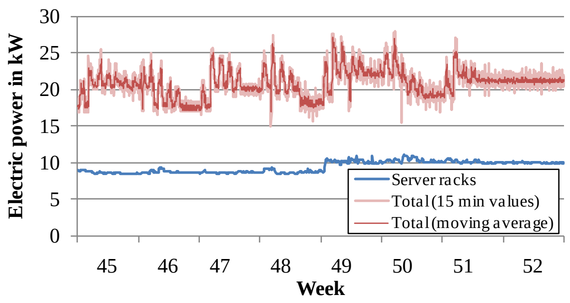

Figure 6. Electrical energy consumption of DC and c²m.

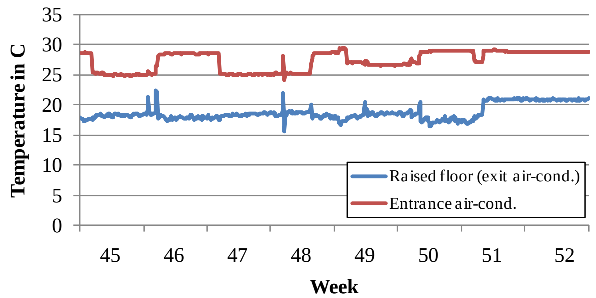

Figure 7. Temperature distribution in the server room.

Weeks with high energy consumption are correlated with a lower temperature of 25 °C at the top of the server racks and a slightly higher temperature in the raised floor. Every Tuesday morning the air-conditioning systems are switched over. The peaks in week 46 and 48 (figure 7) are caused by AC 1. In week 46 there was a malfunction for 120 min and in week 48 the air ventilator located on the roof of the building was covered with ice. In week 51 the exit temperature of AC 2 was increased in order to see the impact on power consumption.

The energy consumptions of the ACs were not monitored continuously, but only in single weeks. The ACs had an almost constant energy consumption of

- AC 1: 7.6 kW
- AC 2: 10.6 kW; 10.1 kW since week 51

in the period between August and December. The difference in the consumption of the two AC units is mainly caused by the fact that the air ventilation (2.36 kW) of AC 1 is not switched off when AC 2 is operating. This results in a higher air flow rate and a lower server rack temperature but also higher energy cost of € 1,570 per year.

The opposite effect can be seen in weeks 51 and 52. Although the exit temperature of AC 2 was increased the temperature at the top of the server racks is as high as in those weeks when AC 1 is operating. First measurements indicate that this measure is not as effective as switching off the air ventilation of AC 1. Nevertheless, it shows that there is room for further optimisation of the AC operation mode.

Summarising this section the following areas for improvement were identified:

- Control of airflow in server racks;
- Further optimisation of AC operation mode;
- Switch off air ventilation of AC 1 when AC 2 is operating.

Another approach to reduce the energy costs significantly is the use of free cooling.

Direct free cooling

When you consider the typical temperature profiles in Augsburg, the air is below 15 °C for 71 % of the time. These figures indicate that the running period and the energy consumption of the air-conditioning system could be reduced significantly by using free cooling. The outside temperature and the required room temperature define the operation mode. Here one has to differentiate between free cooling mode, mixed mode operation (free cooling with additional cooling provided by the cooling cycle) and recirculation mode (cooling via cooling cycle alone) [5].

In direct free cooling, cold outside air is transported into the room. The heat load from the IT equipment is transferred to the air stream and this transports it out of the room. The air current is fed or circulated through an external air filter and a fan unit. This operation mode allows a reduction of 5 to 7 kW. If outside temperatures rise, the air handling control system switches to mixed mode so that additional heat can be removed via the cooling cycle. Now we can estimate the potential of this measure:

5…7 kW · 71 % · 1,310 €/kW a = 4,650…6,510 €/a

5…7 kW · 71 % · 8,760 h/a · 575 g/kWh = 17.9…25 t/a

This estimate highlights the enormous annual cost saving and CO_2 reduction potential. Therefore this option is currently being investigated by the head of the DC.

DC Energy Efficiency

In order to quantify the energy efficiency of DCs, a number of different metrics are being used. Two competing metrics are in wide use: DC infrastructure efficiency (*DCiE*) and power usage effectiveness (*PUE*). Here we use *PUE* which is defined as follows:

PUE = Total Energy for DC/Energy of IT equipment

For example, a *PUE* of 2.0 indicates that for every watt of power consumed by IT equipment, an additional watt is consumed to cool and distribute power to the IT equipment. At present, many DCs operate at a level of 1.3 to 2.2 [6] with an average of two.

The *PUE* ratio is notoriously misquoted as the result depends on the time of day (and time of year) the snapshot is taken. A realistic *PUE* should be measured over a long sampling period to take into account seasonal variation of efficiency. Therefore the *PUE* ratio of the DC at the HS Augsburg was calculated at different points in time (Tab. 1).

Table 1. *PUE* ratio of the DC of the HS Augsburg.

Week	35	47	48	50	52
PUE	2.36	2.26	2.08	1.86	1.96

The calculated *PUE* ratio decreased during the weeks investigated due to the changes of the operation mode of the air-conditioning system. Nevertheless, it is only slightly below the average value of two. This indicates that there is potential for further improvements.

Computer rooms

Figure 8 shows the electrical energy consumption in the computer rooms. The energy consumption in the two wings on this floor is almost identical. Differences on single days can be explained by the degree of utilization and the amount of sunshine.

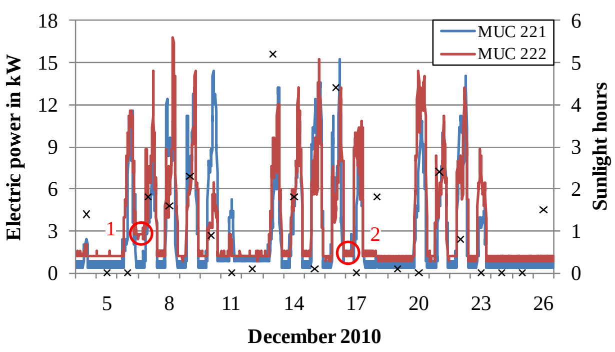

Figure 8. Electrical energy consumption in computer rooms on the 3rd floor and sunlight hours (x) in Augsburg.

The base load of 570 W (MUC 221) during the Christmas holidays results in the lighting of the emergency exits, electromagnetic door releases, access control, hubs and switches in the individual rooms. During the week the loads of the computers and mainly the loads for room lighting are added. The higher base load of 1030 W in the south-west-wing (MUC 222) can be explained by the fact that the iMacs which are located in that wing are not shut down centrally after the DC is closed. Noticeable are also the two marked nights: The light in one computer room (1) and the toilet (2) wasn't switched off. In this building the light is not switched off centrally like in the other buildings. Assuming that this happens twice per month costs of approx. € 100 per year are generated as a result of this.

POTENTIAL OF SMART METERING

By installing intelligent electricity meters areas to use electrical energy more efficiently have already been identified. However the idea of smart metering is to use meters that have advanced features that do more than just measure energy consumption. In this context load shifting, load reduction and load limiting shall only be mentioned.

Load limiting and load shifting in the DC are only possible in very narrow limits. The maximum power consumption in the period of study was 57 kW. It has to be considered that the base load is 20 to 26 kW and another 25 to 30 kW are added by fluctuating consumer use (PC, light, lab equipment, etc.) during the daytime. Limiting and shifting this fluctuating consumption is almost impossible. So only the air-conditioning system offers some margin to limit or shift load. Since the room volume of the DC is very large compared to the space used by the servers it is possible to shift parts of the cooling process to the night and use the air volume as a thermal buffer.

The greatest potential in our application was realized by load reduction. This was possible by making the energy consumption observable and raising the awareness of the consumers to use electrical energy more efficiently.

CONCLUSIONS

The investigations in the DC of the HS Augsburg showed that electrical energy could be used more efficiently than today. Here the cooling of the IT devices plays a key role. The highest cost reduction potential is offered by the use of direct free cooling. Nevertheless, also the other identified measures should be implemented. We can conclude: it has been worthwhile investing in intelligent electricity meters.

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