ENERGYbase: MONITORING OF THE REFERENCE ROOM IN THE OFFICE COMPLEX OF THE FUTURE

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Synopsis

The ENERGYbase office building in Vienna / Austria is designed as a so called »Passivhaus« concerning the architectural building and energy system concept. It aims to achieve three essential targets: high level of energy efficiency of the applied systems, high ratio of renewable and environmental friendly energy use and high indoor comfort for the office building user. The ENERGYbase building, already permanently equipped with a formidable array of sensors, was further examined by placing 50 additional air temperature and 19 air velocity sensors in a reference office room. A special data processing tool was designed for the dissemination of the data collected, and a comprehensive TRNSYS building model was used to determine the impact of actual weather parameters and the results were compared with measured air temperatures for reference periods. The high indoor comfort predicted and the importance of proper shading and glazing in this type of building was verified.

1 Introduction

During the planning phase of ENERGYbase [1, 2] the Austrian Institute of Technology (AIT) applied expert simulation tools in order to support the planning team by providing scientific results on questions which were mainly focused on a) the scientific support of the integrative planning procedure b) the prediction and future monitoring of the energy and thermal building performance and c) detailed comfort analysis for south oriented offices [3] [4].

Since August 2008 the ENERGYbase building is operating. AIT conducts a comprehensive monitoring campaign in order to assess the office building performance in terms of energy and thermal comfort by acquiring, post processing and analyzing measurement data. As part of the monitoring concept already developed during planning phase a reference office room in the 3rd floor in the south west corner of the building is permanently equipped with sensors in order to assess the user thermal comfort.

1.1 Objective of the activity and methodology

The architectural design aim of the high glazed, folded south façade of ENERGYbase is to benefit from high ratio of daylight use in the south oriented office areas, which leads to a significant reduction of electricity demand for artificial lighting. The sensible load of the office rooms is controlled by concrete core activation (CCA) in the floor and ceiling. The comfort targets predicted by simulation results during the planning phase are now assessed by AIT using the permanent and additional temporary monitoring equipment implemented in the reference room. The acquired monitoring data during building operation are used to a) assess the thermal comfort in the reference office, b) get a 3D resolved set of reference office air temperatures in order to identify the impact of solar radiation, ambient air temperature, the operation of the CCA and the air-conditioning (AC) and c) compare results from transient building simulation with the measured air temperatures for selected reference periods. Validated models and methodologies lead to a benefit in predicting the building and energy system performance.

1.2 Temporary monitoring concept and campaign (July – November 2009)

Additionally to the permanent monitoring equipment of the ENERGYbase, AIT set up a temporary array of measurement devices (50 PT100 temperature sensors and 19 hot bulb anemometers to assess air temperature and magnitude of air velocity) from July 22nd until November 16th 2009, while the room was still unoccupied. The sensors were freely suspended at defined points in three vertical planes in the room (Fig. 1).

Measurement planes were selected in relation to the air outlet positions in the room, and the in-house software tool ‘Kraftwerksauswerte- und Messsystem’ (KWAMS) was used to generate and store data with a sampling time of one minute from the sensor readings.

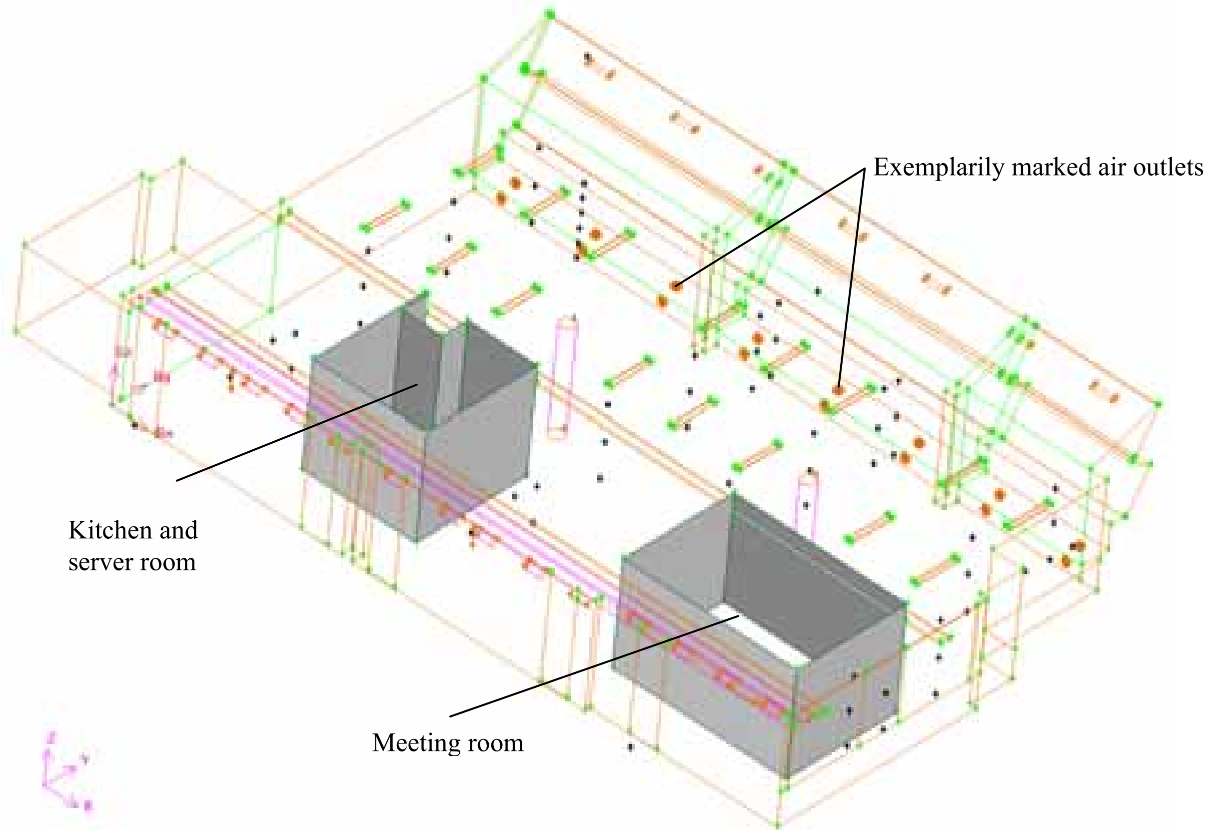

Figure 1: Geometry reference room, with y pointing approximately south. The black vertices are positions of the freely suspended sensors of the temporary monitoring

Figure 2: Photograph of the experimental set up.

1.3 Comparison between transient building simulation and monitoring data

A building model updated with respect to the construction material properties, actual geometry and operation schedules of the applied energy systems – like CCA and AC – was created in the TRNSYS 17 [5] simulation environment. The geometry model was created using Google Sketchup [6] together with the TRNSYS 3D plug-in, and subsequently importing the geometry into TRNBUILD. For the simulation, the actual operation schedules for CCA and AC and manufacturer data for the component were used. Finally the simulation model was fine tuned by practical information provided by the facility management of ENERGYbase and calibrated using monitoring data.

In a first approach the profiles of the mean air temperature in the reference room were investigated to compare simulation and monitoring results. Two different reference periods in the year 2009 –August 31st until September 5th and 9th to 15th of November - were chosen in order to assess the temperature performance under different weather conditions.

The data generated by the simulations will be used to evaluate and predict the building performance and the effect of the schedules of CCA and AC in the office area, taking the special façade into account. As some of the sensors were influenced by direct solar radiation, daylight simulation with Google Sketchup was used to determine those sensors which were actually shaded all the time in the two different periods chosen for assessment. Twelve temperature sensors were determined for the first reference period, while in November only one sensor remained unperturbed by direct solar radiation. Figure 3 and 4 show the simulated mean air temperature in comparison to the mean of measurement data from the chosen sensors.

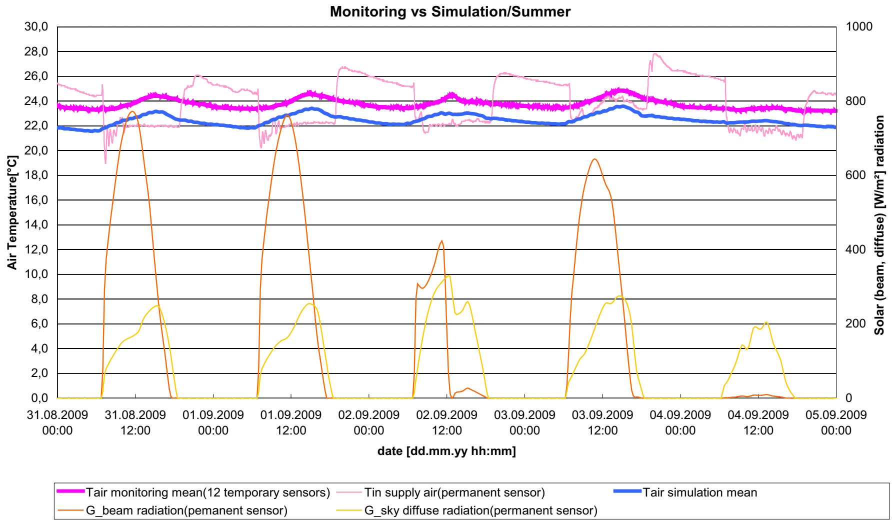

Figure 3: Summer operation reference period (31.08.2009-05.09.2009).

Figure 3 illustrates air temperature and solar radiation profiles of the summer operation period from August 31st until September 5th for the following variables:

- *Tair monitoring mean* represents the average air temperature value calculated out of 12 selected temperature sensors from the temporary monitoring sensor set without any influence by direct solar radiation,
- *Tin supply air* represents the temperature of the air supplied by the AC system
- *Tair simulation* represents the simulated air temperature of the reference room modeled by a single air-node,
- *G_beam radiation* and *G_sky* represent measured direct and diffuse radiation on horizontal surfaces

During the selected summer period the AC system is used from 7 a.m. to 7 p.m., while the pumps of the CCA are used 20 hours daily (10p.m. to 6 p.m.). The first two days of this period (Fig. 3) featured a cloudless sunny sky. Due to the shape of the south façade, the impact of the beam radiation on the indoor air temperature is nearly the same as on the other days, which show much lower values for the direct radiation. The average air temperature based on the 12 selected temperature sensors is between 23°C and 25°C over the first reference period. The comparison between the air temperature of simulation and monitoring results shows a good correlation, and reproduces the thermal inertia and amplitudes well. Nevertheless the simulation results have an offset of around 1.5°K.

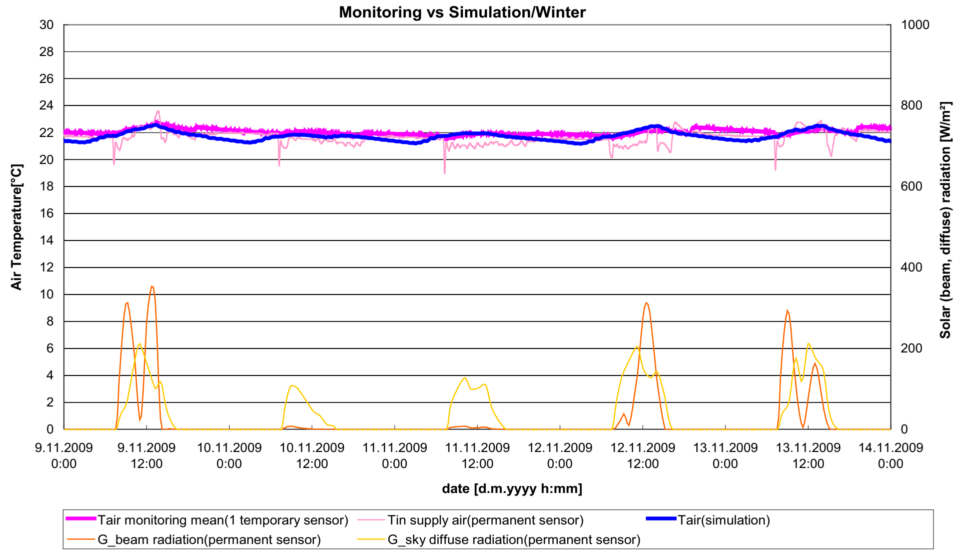

Figure 4: Transition time reference period (09.11.2009-14.11.2009)

Figure 4 shows the course of air temperature and solar radiation from November 9th until November 14th 2009. In the selected period the solar radiation never exceeded 350 W/m². Due to the characteristic sun path the geometry of the south façade allows for more direct solar radiation in the reference room. In this case the simulation results are even closer to the measurements.

2 Results and Conclusion

Due to the huge amount of data gathered by the sensors temporally placed into the reference room, as well as by the sensors permanently implemented into ENEGRYbase, a custom post processing tool was created and applied. The tool of choice was the MATLAB computing environment, as it offers both the capabilities for working easily and fast with bigger data sets, as well as the possibility to create graphical user interfaces (GUIs) with the aid of a comfortable drag and drop editor.

Using MATLAB, scripts were written that reformat the text output files from the KWAMS as well as the Excel files provided from the ADP (Advanced Data Processing) database of the permanent monitoring into a common data structure. The geometry of the room and the coordinates of the sensors were combined with this data in a GUI which allows a freely moveable view of the room and the sensors. Including warnings for data disturbed by persons working inside the room, the possibility to display the timeline for a data point and most important controls to go back and forward in time to get an overview of the situation over time.

The solar radiation impact on the room air temperature is significantly reduced by proper façade design, operation of CCA and AC (Fig.3). A major part of the compensation is achieved by the special design the south façade in combination with automatic external blinds on the west windows which avoid uncomfortable high air temperature peaks forced by direct sunlight.

The permanent monitoring system implemented in the ENERGYbase office building enables to assess the real energy performance of the overall building and subsystems and to validate theoretical models implemented in simulation tools. Figures 3 and 4 prove that simulation tool chosen is sufficient to predict both the building energy performance and the thermal comfort of offices of future building concepts.

The sensible load of ENERGYbase offices is controlled by CCA. Additionally the design of the south façade protects the office rooms against external loads namely by high direct solar radiation. The acquired monitoring data document on thermal response in case of high solar radiation during summer and transition season. Herewith it can be stated that the developed architectural and energy system concept supports significantly to indoor user comfort. Based on the conducted monitoring period from July 22nd 09 till November 16th 2009 the air temperatures in the reference office are homogenously distributed in space and most are in the temperature range between 20°C and 25°C. In transition time periods with high solar radiation air temperature peaks only appeared up to 32°C close to the south oriented façade, which has a positive impact on the efficiency of heat recovery of the air-conditioning system (Fig 5.).

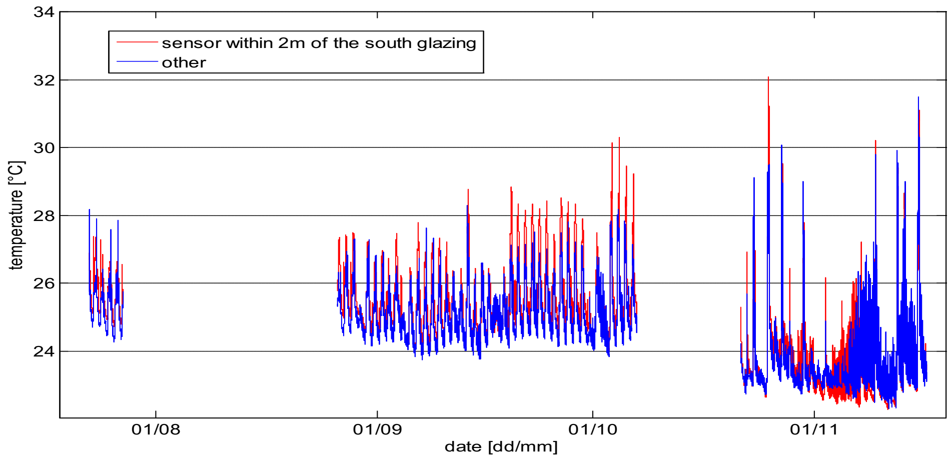

Figure 5: Maxima of the two temperature sensor groups of the temporary monitoring

To asses the effect of the folded façade of the ENERGYbase, the temporary sensors were divided into two groups for post processing. One is formed by those temperature sensors which are within two meters of the south façade, the rest forming the other group. In Fig. 5, the maximum values found for each of the two groups for all instances in time are shown in comparison to each other. In summer, the two groups show a very similar behavior due to the shading effect of the folded façade, while in September and October, the maxima of the group close to the façade have a tendency to reach higher values. Finally in November solar radiation influences most of the office leading to high temperature maxima, but is compensated by CCA and AC with respect to the mean room temperature.

A comparison of monitoring data and transient building simulation of the reference room shows good correlation, but the model has been optimized especially related to impact of solar radiation. In further research activities AIT is going to use the acquired data set in order to compare with CFD results.

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