Case Study summary

IEA-ECBCS Annex 48

Heat Pumping and Reversible Air Conditioning



German Case Study N° 1: a large office building in Münster, heated and cooled with geothermal energy

Contribution of:

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Introduction

The LVM office building is a combination of a new building (10 000 m² floor area, completion 8/2008) with a retrofit (4 000 m² floor area, completion 2/2010).

A geothermal reversible heat pump system provides the necessary energy for the thermal room conditioning. For simultaneous heating and cooling in different sections of the building a supply system consisting of 3 pipes were installed.
A new control strategy for tabs was used.

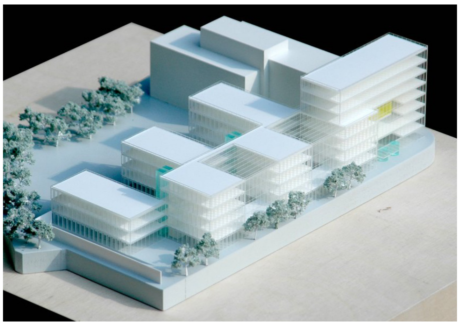
The building, the tabs, the control and the geothermal bore hole heat exchanger were simulated with a special software. To verify the energetic behaviour of the building, energy consumption and thermal comfort, a monitoring system was installed.

Summary

- Location: Münster, Germany
- Building sector: office
- conditioned floor area: 14 000 m²
- mean number of occupants: 800
- naturally ventilated
- tabs for heating and cooling
- radiators for additional and individual heating
- geothermal energy use:
  - 91 bore hole heat exchangers
  - reversible heat pump
- heating power: 530 kW
- cooling power: 380 kW

Building

The high glazed façade, with coloured elements, has an external shading system, automatically adjusted to the solar position and irradiance. Two large atriums, planted with palms, are arranged in the middle, the glazed roof covered with photovoltaic. The adjacent offices are supplied through the atria with fresh air. Those located on the façade are naturally ventilated by small windows.
The rooms are heated and cooled by tabs, radiators are used for additional room by room heating in the morning hours.



View from the south to the design model

Technical concept

A geothermal reversible heat pump provides the necessary energy for heating and cooling for the total building complex: the new building and the retrofit.
The ground heat exchanger consists of 91 double u-shaped probes, each 100 m deep, located under the underground car park. The holes were filled with a highly heat-conductive material in order to guarantee a good soil contact. The probes are filled with a water glycol mixture and are connected via two manifolds to the heat pump.
The heat pump system consists of 2 separated machines in cascade with 2 power regimes each: Hp1: 180 kW or 360 kW, Hp2: 70 kW or 140 kW, which allows 8 different adapted power combinations. Two storages, a cold and a hot, with 10 m³ each, act as a decoupling to the building and increase the operation time of the heat pump. The hydraulic scheme allows a simultaneous heating and cooling of the rooms.
A very energy efficient operation mode is the free cooling of the building, without the use of the heat pump, provided that the ground temperatures are cold enough.

For backup and higher temperatures, heating coil for ventilation or DHW production, a district heating is integrated into the system.

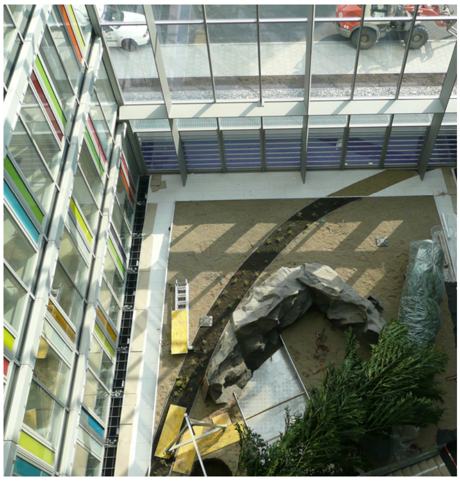
Tabs, thermal active building systems, are installed in the concrete ceiling, covering up to 90 % of the area, with a distance between the pipes of 15 – 20 cm and a flow rate of 10 kg/h m². The supply temperature is in the range of 16 – 30 °C.

A BEMS manages the whole system: operation mode of the heat pump, supply temperature for the tabs, and allows the monitoring of more than 100 data variables.

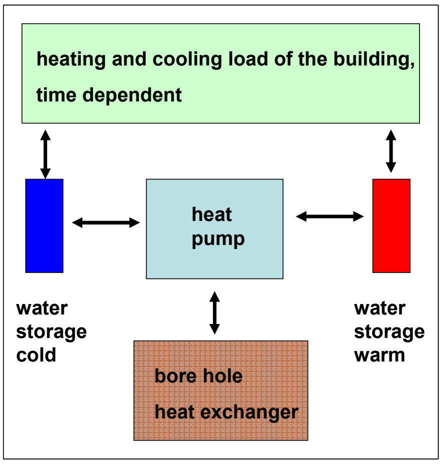
The atrium with the photovoltaic

Simulation

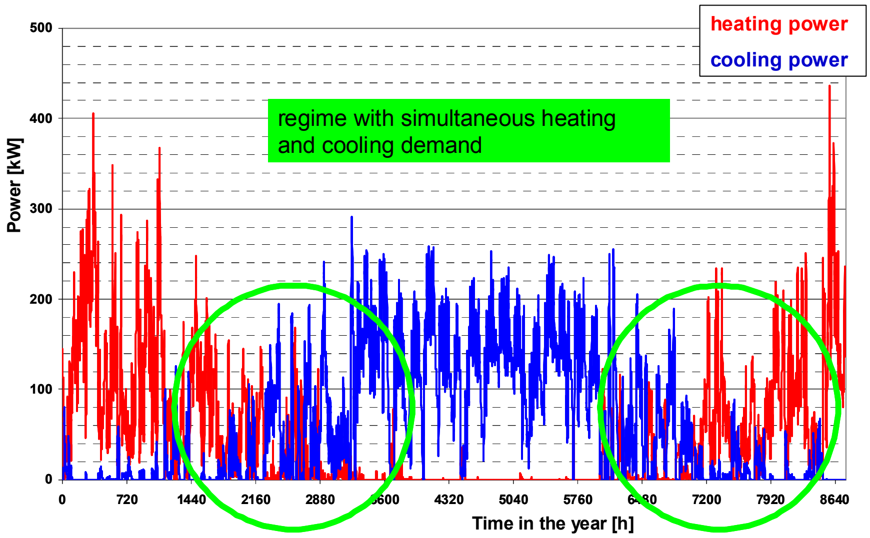
The thermal and energetic behavior of the building in the interaction with the heat pump and the ground heat exchanger was studied within a dynamic simulation (Trnsys). In the foreground was the question of thermal comfort in differently oriented rooms, in addition with a reduce in energy consumption. The effect of the new control strategy for tabs could be examined. For the design of the ground heat exchanger the simulation with realistic heating and cooling load profiles gives valuable information on temperature levels. Those determined directly the COP of the heat pump.
For the offices oriented to the atrium, the quality of air flow in the atrium is essential for the hygienic air change in the rooms. A CFD simulation showed the flow path of the fresh air and the influence and need of obstacles to redirect the air to the rooms. As a consequence, an artificial rock was inserted.



The artificial rock as air obstacle



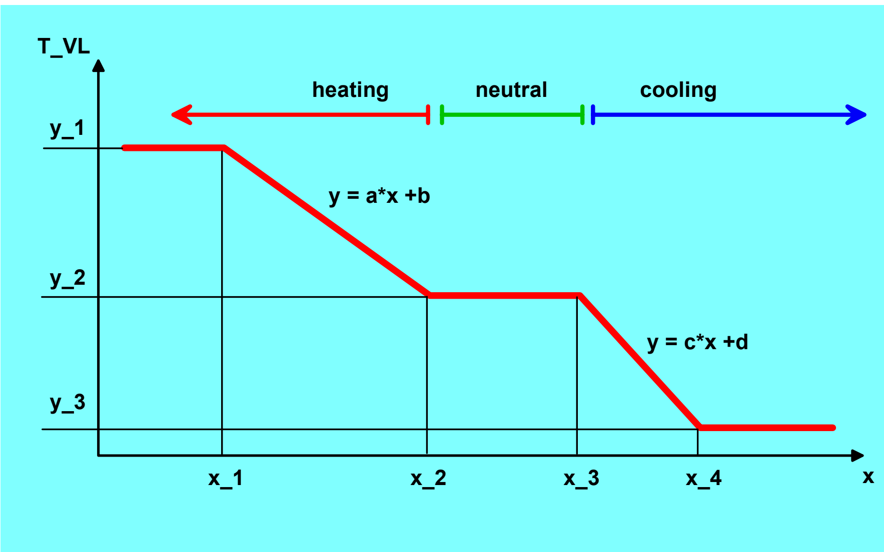
Geothermal energy concept



Heating and cooling load over the year

Control for tabs

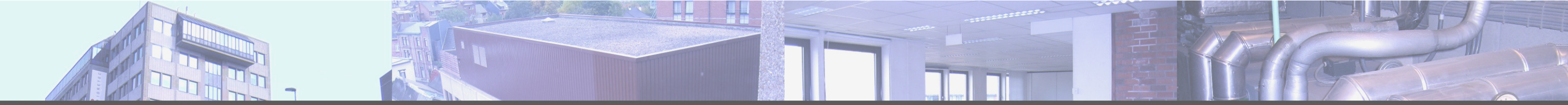
The inertia of the concrete core cooling and heating system requires a modified control system for the supply temperature to establish an optimal temperature comfort in the rooms and a reduced energy consumption.
In the control strategy used here, the set temperature of the tabs is based on a simple linear approach. The controlled variable is composed of weather features, such as temperature (T) and solar radiation (S), which are the main external loads acting on the room. In order to take the inertia of the system into account not the actual values are used, but 24-h mean values. The parameters of the control, such as temperature levels for the heating and cooling regime or the parameters in the linear equation are adapted to the building temperature reaction iterative.



$$T\_VL = fkt(x)$$

$$x = fkt(T\_24, S\_24, \Delta T\_24)$$

Supply temperature of the tabs with the new control strategy

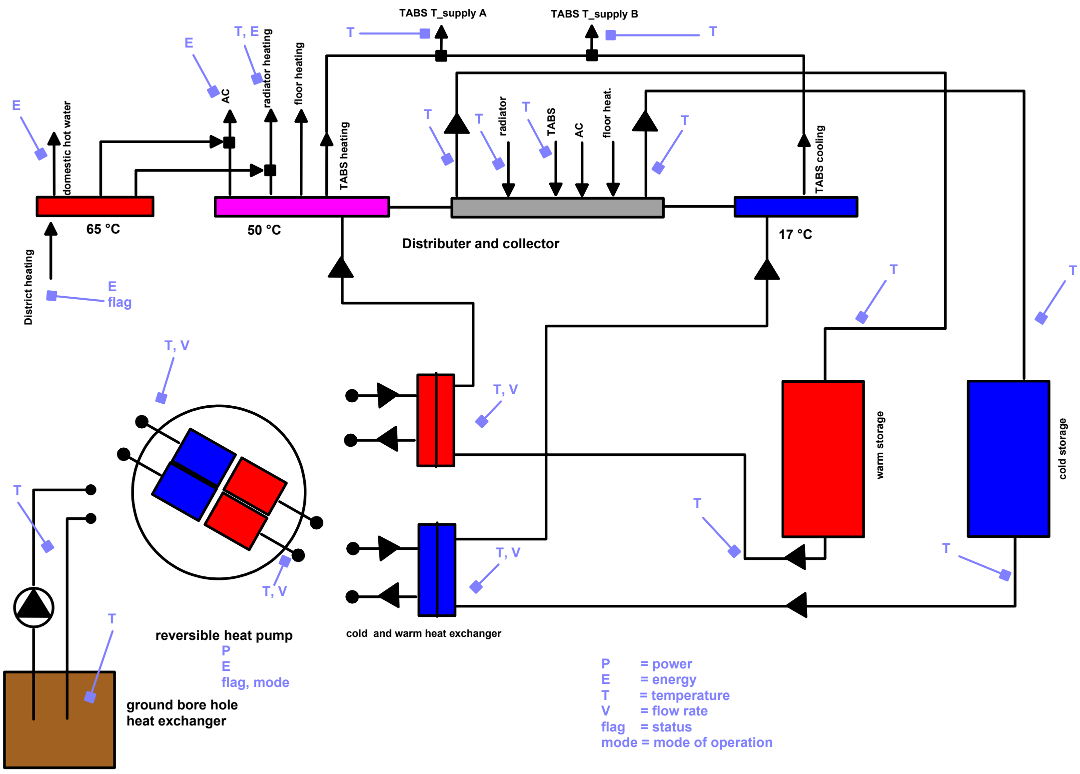


Monitoring

The data monitoring is integrated in the BEMS. About 100 data points are collected every 15 minutes and stored in a spreadsheet. The instrumentation requirements include the type, accuracy, acquisition frequency and sensor placement were defined.
An important aspect of the monitoring is system operation optimisation. This is particularly relevant to innovative, complex plants – as HP-based systems often are – in which the actual energy performance depends primarily on the efficacy of the control strategy being implemented. The concept of “system monitoring” can be also considered as an integral part of the commissioning process.
The data analyses gives information about:

- Fault detection
    - Software
    - adjustments
- system performance
    - hydraulic, heat pump, ground heat exchanger
    - control strategy
    - room temperature, comfort
- energy optimization
    - COP of the heat pump
    - Total energy consumption

Due to the completion of the overall system with the commissioning of the retrofit building in 2/2010, the monitoring provides reliable and complete data only since a few months. First results from the analyses show stable temperature conditions in the ground and a large period of free cooling in summer.



Location of the sensors for the data monitoring in the hydraulic scheme

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IEA-ECBCS Annex 48 is a research project on reversible air conditioning systems in the tertiary sector. The project is accomplished in Energy Conservation in Buildings and Community Systems Programme of the International Energy Agency (IEA).

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