

Design and integration of heat pumps for nearly Zero Energy Buildings



nZEB office building Post am Rochus

Integrale Planning and Commissioning of nZEB office in Vienna

Summary

The nZEB office building "Post am Rochus" in Vienna is the new headquarter of the Austrian Post AG. In a lighthouse research project the integral planning in a complex multi-stakeholder process to improve time-, cost- and energy-efficiency for the implementation of complex nZEB was investigated. A simulation-based approach and a hardware-in-the-loop controller testing was applied to drastically shorten the commissioning phase. A functional quality management and pre-tested overall control strategies were identified as two success factors for energy-efficiency. Regularly workshops to guarantee information flow among the engineering teams shall be continued into the operation phase, in order to transfer know-how gathered in the planning/commissioning. IT-solutions like BIM and digital twins can further enhance the data flow and performance. Legally, the role of simulation results has to be clarified. Building performance indicators shall be based on an updated "as-built" situation, in particular for contracting models.

Building Data

Location:	Vienna/ Austria
Building Use:	office/retail (ground)
Gross (useful) floor area:	49,300 (42,449) m ²
Walls new (refurbished)	0.15 (0.09) W/(m ² K)
Roof:	0.11 W/(m ² K)
Ground floor:	0.30 W/(m ² K)
Windows new:	0.77 (1.70) W/(m ² K)
	triple glazing, g= 0,5
Windows refurbished:	1.70W/(m ² K); double/ single glazing, g= 0.6
Heating demand:	10.64 kWh/(m ² a) (offices) 9.61 kWh/(m ² a) (retail)
Cooling demand:	16.33 kWh/(m ² a) (offices) 12.74 kWh/(m ² a) (retail)
Certificate:	ÖGNI GOLD
Awards:	Staatspreis Architektur in der Kategorie "Verwaltung" 2018 Office of the Year 2017

June 2020



International Energy Agency

Heat Pumping Technologies



Background

The building owner's goal was to plan, build and use a modern, comfortable building with very high standards of sustainability and energy efficiency not only on paper, but also in the construction, commissioning and operation. Therefore, the building project was supported by research experts from the Austrian Institute of Technology (AIT). The overall objective was to shorten the commissioning phase by detailed investigation and optimization of the control strategies of the HVAC. By applying an integral planning construction/operation companies teamed-up with experts. The results were not only clearly documented, but control strategies were also tested by hardware in advance, thus malfunctioning was detected, avoided and corrected. The contracted companies were also actively involved and mainly contributed to the final control strategy.

Technical concept

The following technical features characterize the HVAC concepts: Three highly energy-efficient compression chillers of 1 MW (thermal) capacity each guarantee the space cooling, while the heat is recovered during the cooling period with a re-heating register during dehumidification. A 320 m³ sprinkler water basin is used as cold storage for free cooling. The concrete core activation of building elements is used for high-temperature cooling and the central air-handling unit is equipped with a latent and sensitive recovery system (enthalpy rotor with bypass).

The warm water pumped through both the concrete core activation and the heat exchangers of the central air-handling unit is heated by the local district heating network. Hot water is produced by decentral electric flow heaters.

Current market state

Integral planning methods are more and more introduced, in particular for larger buildings. Hardware testing of the control system, though, is not a standard today and simulation accompanied commissioning phase is also a new application which is rather in pilot and demonstration stage. However, project results confirm that these strategies can accelerate commissioning, especially for complex systems.

Technical data of the unit

Heat transfer system:

Thermally activated building elements + FanCoils

Chilled water production:

Three highly efficient compression chillers (1 MW_{th} each)

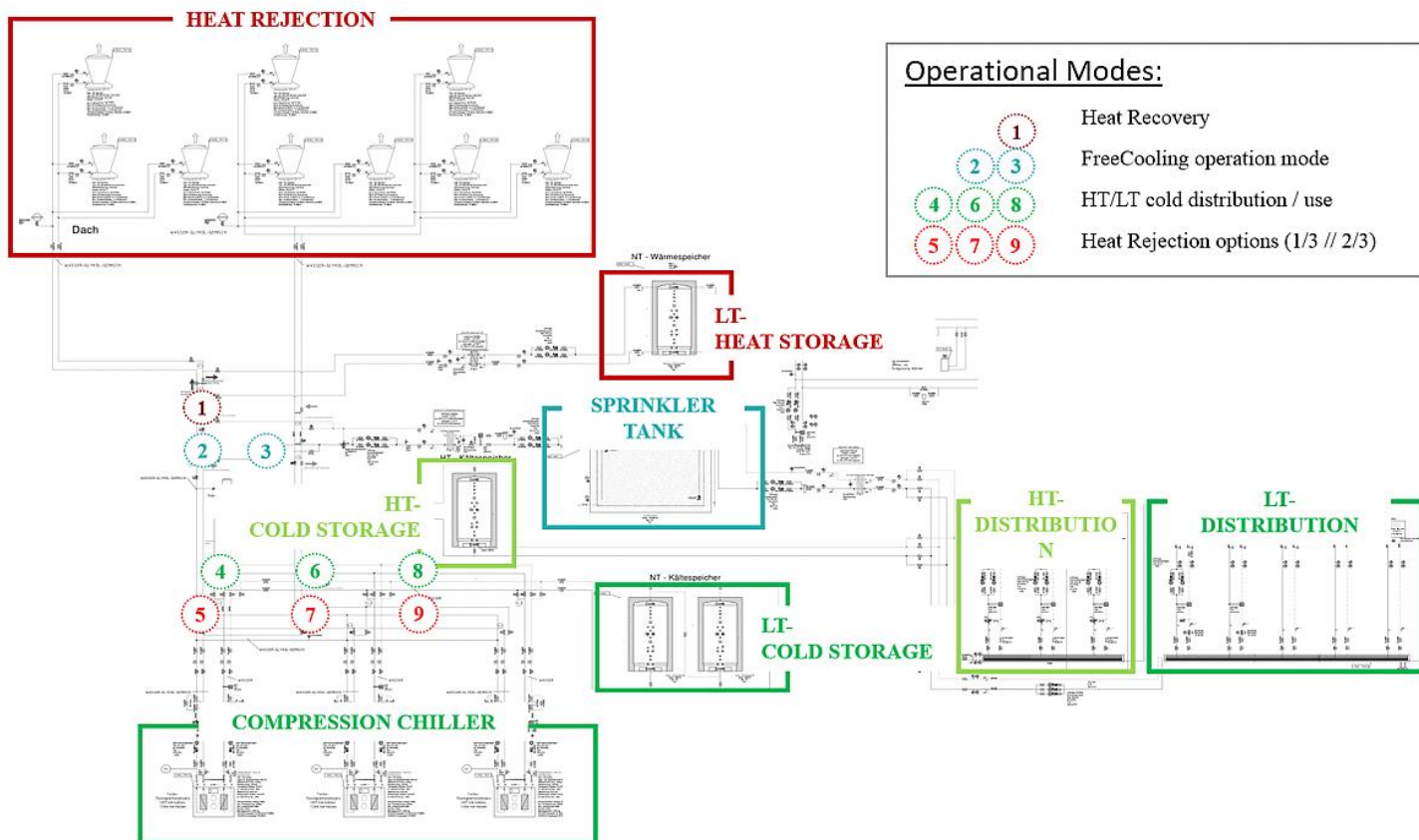
Heating system:

Local district heating system

Ventilation system

Central air treatment system with sensible and latent heat recovery

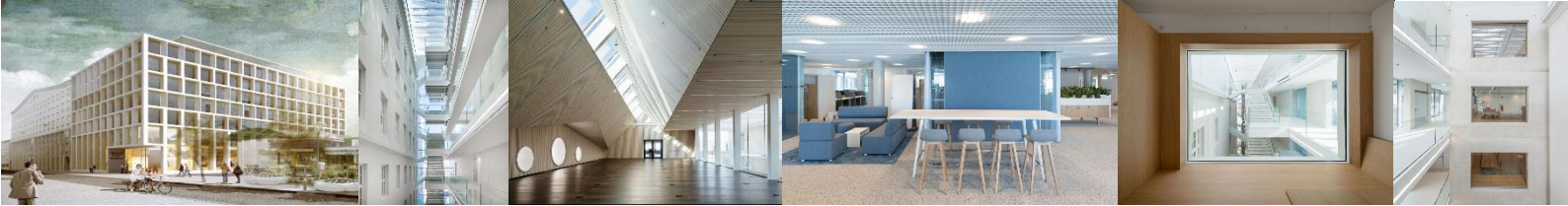
Volume flow rate office	67,000 m ³ /h
Volume flow rate retail	87,000 m ³ /h
(CO ₂ -control)	
Heat recovery	73%



Operational Modes:

- 1 Heat Recovery
- 2 3 FreeCooling operation mode
- 4 6 8 HT/LT cold distribution / use
- 5 7 9 Heat Rejection options (1/3 // 2/3)

System configuration with key thermal system components and operation modes



Process Planning - commissioning - operation

The ambitious goal to drastically shorten the commissioning phase led to involvement of all relevant parties (HVAC planners, instrumentation/control engineers, owners and operators) two years before commissioning. The commissioning was thus started with detailed system understanding and effective control strategies. The involved parties were well informed of the functionalities of the control and its set points and performance targets. The AIT produced a data basis generated by numerous dynamic simulations to predict, check and optimize the control and to implement best settings in the building management system (BMS).

Within the research project, nine different operating modes were identified. For each operating mode, cost-optimized control strategies were defined and checked by parameter variations, e.g. for set points, hysteresis, schedules and cross-dependency (power cascades). The simulation results led to a database that provide control engineers and operators with practical instructions for programming, well-functioning operation and troubleshooting. All involved parties had access to this "function manual".

After the implementation of the control strategies into the BMS, certain parts of the building automation were tested using the "controller-in-the-loop" approach, which allows to test strategies on the controller hard-/software in the building automation system. Prior the implementation into the BMS, functional tests were performed for all operating modes independent of actual weather conditions during commissioning, which is an important advantage since cooling systems can hardly be fully tested during the heating period. This "controller-in-the-loop" approach reduces the commissioning time, as errors and mal-functioning can be detected before the BMS is finally implemented in the building.

A transient building and system modelling in TRNSYS 17.02 was used by all team members involved. Due to the complexity of the modelling/simulation tasks and to facilitate the workflows, the HVAC overall model was divided into three independently functioning, decoupled sub-models.

1. Multi-zone building model: Optimization of the shell, development of the control strategy for concrete core activation, calculation of the heating and cooling loads (input for the thermal system)
2. Thermal (cooling) system: Development of the control strategy and optimization of all operating modes
3. Air-treatment system: Development/optimization of the control of different operating modes of the air handling units

The simulation results of the sub-models were validated individually and used as input for the cooling system model. The cooling load profiles calculated by the multi-zone building and the air-treatment model represent to different temperature levels

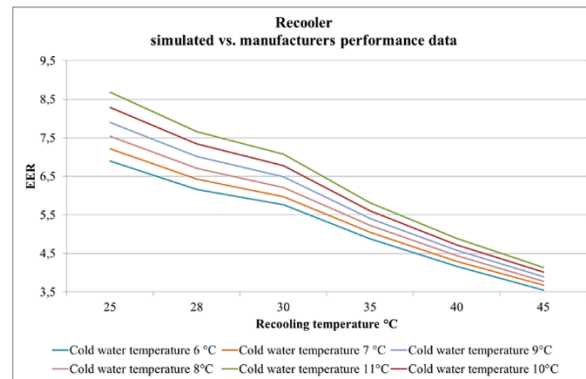
- a) cold water temperatures for the concrete core activation and
- b) chilled water temperatures for fan-coils and cooling registers of the air-handling-units.

Standard load curves (SIA 2024) were used of the supermarket and server rooms. In a first step within the model creation phase, the main tendered technical HVAC components were modelled and validated against the manufacturers' data sheets. The modeling and simulations approach was chosen for two purposes:

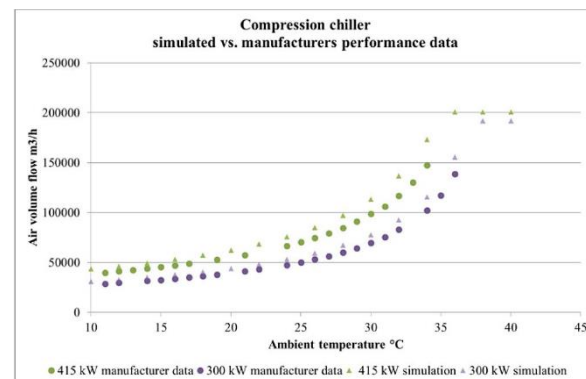
- a) to analyze typical/potential failures reported by the facility management of similar components/plants,
- b) to optimize control strategies.

Parameter variations of the high and low temperature circuits were performed to identify the cost-optimal configuration. The optimization method was applied for following technical subsystems and/or components:

- a) Fan-coils, b) server rooms and c) concrete core activation
- d) the discharge strategies for the thermal storages, e) heat rejection system and f) all three compression chillers.



Chiller performance map for recooling operation



Comparison on simulated data to manufacturer data

Building performance

From a legal point of view, it must be clearly regulated how the simulation results are dealt with in the context of the construction project, i.e. whether it is merely additional information, or the simulation results are a reliable data base for the functional technical description. Another legal issue is the operator contract (FM). Those contracts contain often "energy saving targets", usually indicated in relative savings compared to the energy consumption of previous periods in the first 3-5 years of operation. This is obviously not the best solution, since at least the first year of operation is not representative for the normal operation! Using the energy target values from the design phase is not feasible, either, since many changes during the planning and construction occur, e.g. lower internal cooling loads due to new technologies such as LED. This requires a recalibration of the existing and created building and energy systems models with "as-built" values. Thus, simulation results should be validated by monitoring data. This "as-built" model would provide a digital data and information baseline, updateable over the entire life cycle of the building in form of a digital twin. In addition, this digital twin would be capable to automatically detect faults, mal-functioning and inefficiencies. Thereby, the quality of the entire building process is generally improvable and a check can be made that theoretic potentials for energy savings and high indoor comfort is met.



Commissioning phase

The objective was to drastically shorten the commissioning. Unfortunately, the test operation of the HVAC system could not take place as planned due to construction delays, which led to quick building occupation. Based on the experience, a successful commissioning is supported by:

- Functional quality management (QM) at component level
- Correct functioning of the entire hydraulic system including extensive hydraulic balancing
- Clear documentation on the functioning of major components (automation, performance targets, setpoints, etc.)
- Definition of suitable and pre-tested overall control strategies and operating modes for the overall HVAC system.

A QM is recommended for the commissioning for achieving energy-efficiency. Thus, main operation and process steps to be tested shall be defined with control engineers. The building owner was actively involved and based on its experience in technical Facility Management (FM), both promoting and demanding contributions were made. The feedback was positive, as costly failures and delays were avoided at an early stage. Maintaining an interdisciplinary approach during construction/commissioning was essential for efficient building operation. The QM process should include the FM. The integral planning, the use of advanced simulation and discussions on new technical/process solutions on regular workshops determines the success and shall be continued during early operation, as the built-up know-how of the system operation should be used. Errors, mal-functioning and inefficient operation as well as improvements can then be immediately identified and implemented. Although the commission is often time-critical (and in reality often skipped/delayed), sufficient time should be reserved for acceptance, handover and test operation of the HVAC and its automation system (including all sensors, actuators and data handling/visualization). These processes must be carried out and documented in a well-structured and coordinated manner. Special attention should also be paid to legal/contractual conditions in the early planning, as most of all efforts in the planning/construction phase culminate into these issues.

Conclusion of the integral planning process

Despite the successful project there is still a long way to go. The common establishment and acceptance of the integral planning and "educated commissioning" in the practice of complex NZEBs will take a while. The usage of transient energy simulations and its interpretation by experts helps optimizing the building automation at an early stage, as it is an essential prerequisite for a successful implementation of high-quality and comfortable nZEB.

An integration of heat pumps into the energy system functions well with an integral approach. In practice, a lack of information concerning technical data and energy performance is typical in the early planning phase and during implementation, which leads to assumptions by planners and influence the quality and reliability of design decisions. The time required to create complex models incl. troubleshooting, plausibility checks and visualization of the results is problematic, since decisions are often time critical.

The applied decoupling of building and system models has proven to be feasible for specific investigations. The sub-systems are treated independently, since the energy loads were synchronized and the thermal comfort was guaranteed. For scenarios, where the activation of building mass is part of the energy system, a coupling of both system models is a must. Hydraulic problems occurred during the commissioning that caused a suboptimal operation of the free cooling and on-off cycling of the chiller. In this specific case, the mechanical dampers could not open the circuit for free cooling. For certain key fluid components, it is advantageous to perform some fluid dynamic calculation/simulation, either by experienced experts or preferably in the long run by data driven methods. Therefore, the digitalization of all relevant data is an essential prerequisite, the digitalization of information and data is expected to make remarkable progress in the coming years, especially driven by the rapid development of the Building Information Modeling (BIM) industry. This BIM reduce data losses, which typically occurs at all building development phases and in-between different disciplines and software tools. In particular, integrating simulation methods into BIM will unlock further potentials for energy efficiency and controller optimization.

Imprint

Building owner

Österreichische Post AG

Scientific partner

Philip Horn

Austrian Institute of Technology AIT

This research project 'PEAR' was funded by the Austrian Ministry for Transport, Innovation and Technology with the programme 'Stadt der Zukunft' 2nd Call in 2015.

Literature references

Horn, P, Hauer, S, Bres, A, Eder, K, Lindmeier, I, Frey, A. 2019

Educated commissioning and operation of a complex nearly zero energy office building with the help of dynamic thermal simulations - a best practice report from the Austrian postal test HVAC-service headquarter Post am Rochus
Journal of Physics: Conference Series, 1343 (2019) 012137
Cisbat 2019, doi: 10.1088/1742-6596/1343/1/012137

IEA HPT Annex 49

IEA HPT Annex 49 is a corporate research project on heat pump design and integration in nearly Zero Energy Buildings.

The project is accomplished in the Heat Pump Technologies (HPT) Technology Collaboration Programme (TCP) of the International Energy Agency (IEA).

Internet: <http://www.heatpumpingtechnologies.org/annex49>

