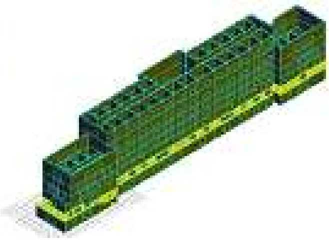
Case Study summary

IEA-ECBCS Annex 48

Heat Pumping and Reversible Air Conditioning



China Case Study N°1: an 8-storey office building in Beijing

Contribution of the Tsinghua University, China

Introduction

This Summary gives field monitoring result of a medium size office building built in Beijing (China) in 2005. There're totally 8 floors including an underground floor, with the total building area 15797 m^2.

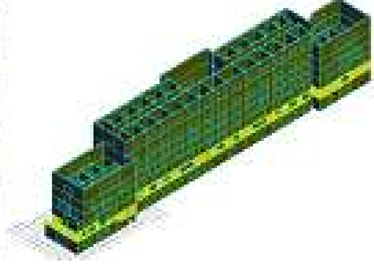
About 50 people occupy each of these floors from 8 am to 6 pm, 5 days a week. After the retrofit in 2003, 24 VRF systems (KX series by Mitsubishi Heavy Industry Co. Ltd.) and 1 fresh air handling system were installed in this building, which are mainly used for cooling, while also for heating as the supplementary of a boiler hot water system. The nominal total cooling capacity of VRF systems are 480HP. There're totally 263 indoor units distributed over the 8 floors and the set temperatures can independently be adjusted by occupants understand the suggested value 26℃. For most systems there's no fresh air handling units and fresh air were introduced directly through opening windows.

Summary

- Location: Beijing, China
- Building sector: office
- Gross net area: 15 797 m^2
- VRF nominal cooling capacity: 480 HP
- FAHU nominal heating capacity: 10 HP
- U-value external walls: 0,80 $W/(m^2K)$
- U-value windows: 2,80 $W/(m^2K)$

International Energy Agency

ECBCS

Background

The aim of this audit and monitoring of this building was to examine the energy efficiency of the building, especially HVAC systems, after the retrofit in 2003. This is an typical example of VRF systems used in medium size office building, and it's necessary to audit the operation of them and point out necessary further retrofit measures to improve the energy efficiency of this building in a further step. Meanwhile, it's a typical case study on heat pumping and reversible air conditioning systems, which is one of the objectives of the IEA-ECBCS Annex 48 project.

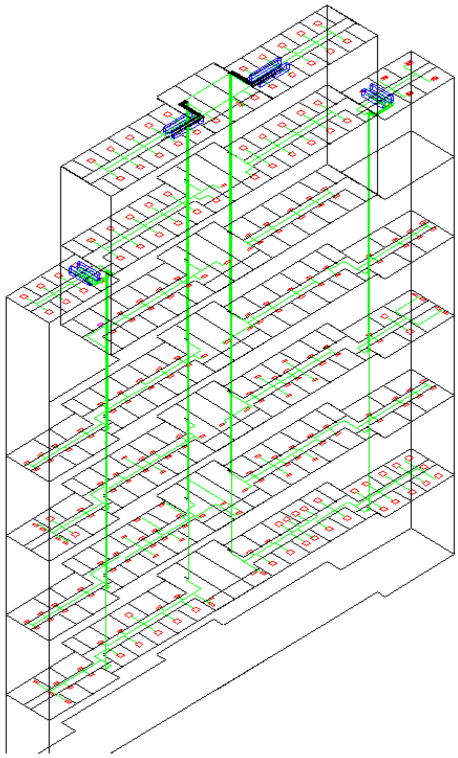
Technical concept

After the retrofit in 2003, totally 24 VRF systems and 1 FAHU (Fresh Air Handling Unit) from MHI (Mitsubishi Heavy Industry Co. Ltd.) were installed in this building which are mainly used for cooling, while also for heating as the supplementary of a boiler hot water system. The total nominal cooling capacity of VRF systems is 480 HP and the nominal cooling capacity of FAHU is 10 HP. There're totally 263 indoor units in all the systems with the total nominal fan power 9.11 kW.

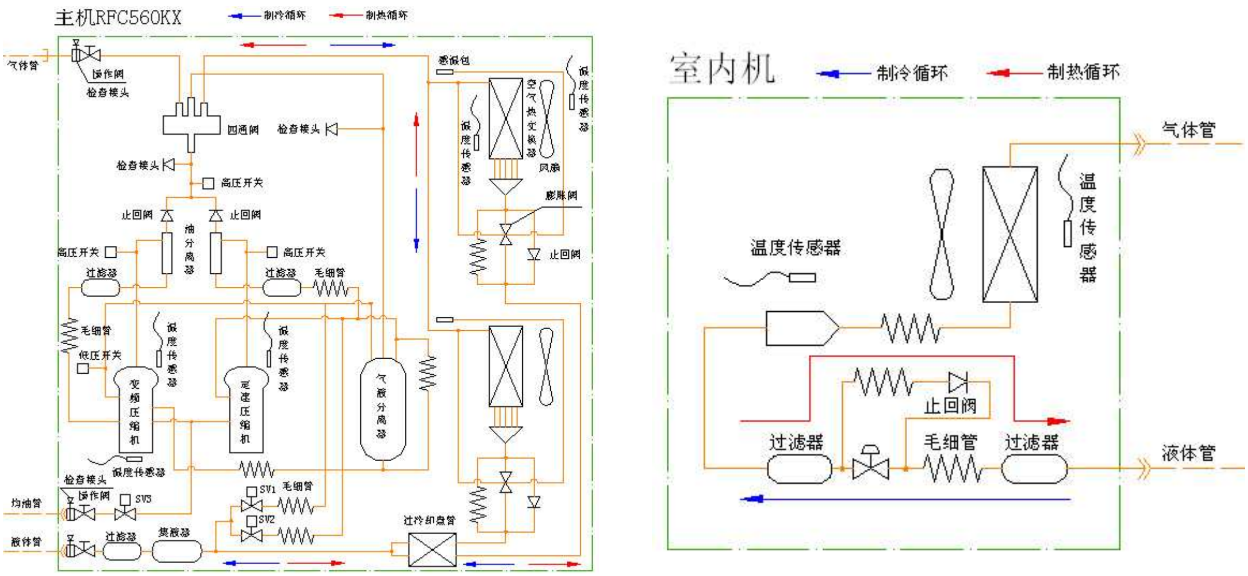
The building were divided into 4 regions from south to north, the two regions in the middle have 8 floors each while the two side regions have 5 floors each. The 24 VRF outdoor units were all placed in 4 groups in the roofs of each region. The numbers of indoor units in each system are from 5 to 16, and the indoor units in a system are distributed in the same floor.

Each outdoor unit is composed of one sub-unit with variable-frequency compressor and several sub-units with constant-speed compressors. The nominal capacity of each sub-unit is 10 HP.

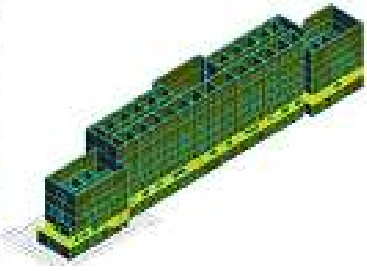
For most VRF systems, there's no FAHU and fresh air were introduced directly through opening windows when people needed.



VRF system zoning and pipe network



Structures of outdoor unit and indoor unit

Audit Part 1: Analysis of historical elec. data

For the audit of energy efficiency of VRF systems, both historical data on electricity consumption and field monitoring data were analyzed.

The historical data were recorded by sub-item power counters. In the year 2004, the VRF systems costs 20.48 kWH/(m^2.a), with the outdoor units taking up more than 90% of the electricity consumption. Comparing the electricity consumption of outdoor units in 4 quarters of the year, we found that besides the cooling conditions in Quarter 3, the power cost in the transition seasons (Quarter 2&4) and heating conditions took half of the total power of the year.

Considering that the VRF systems were mainly set for cooling, there's large potential in saving the electricity in Quarter 1, 2 and 4. The building enclosure is heavy type and there're windows in almost all the rooms so that in transition seasons, natural ventilation can be better used by opening windows and it can tremendously reduce cooling load. In heating season, the VRF systems were only used as supplementary heating system for the boiler hot water system. They were operated in very low part load ratio which caused low COP. So we suggested that the VRF systems should be shut down in heating season, and the building should only rely on the boiler hot water system for heating supply. It was estimated that the shut down of VRF in heating season can save 65 000 kWH of electricity.

Field monitoring materials

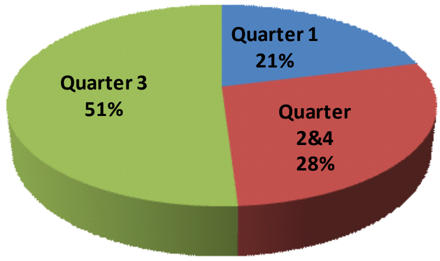
- VRF system service checkers from manufacturer
- Hot-bulb air velocity sensors
- Self-record Temperature sensors

Service Checker and Sensors

Electricity consumption of VRF systems in the year 2004

kWH/(m2.a)

Outdoor Units	Indoor Units	Total
19.38	1.1	20.48



Proportions of outdoor units electricity consumption in different quarters around the year

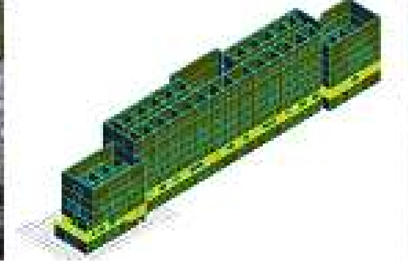
Audit Part 2: Field monitoring results

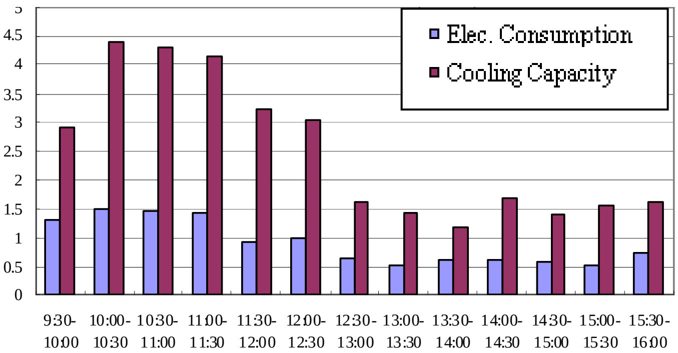
In field monitoring, self-recorded sensors were fixed to test hourly COP of VRF systems. The exhausting heat *Qc* from the outdoor unit was estimated by the tested inlet and outlet air temperatures and velocities. The electricity consumption *W* was directly read from service checker and power counters. System COP was estimated by: $COP = (Qc-W) / W$.

Four systems which serve for floor 1, 4, 5 and 7 were tested and compared. From the tested hourly cooling capacity and electricity consumption results in a typical working day, we can tell the following:

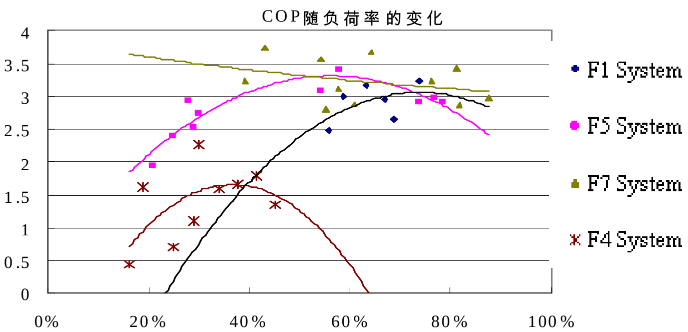
- The COP varies with part load ratio, and the peak COP value appears in the part load ratio region (55%, 80%). The highest COP value appears in 58% part load ratio in the system serving Floor 7.
- COPs of systems serving for different floors were different with each other due to the influence of refrigerant pipe. The system which serves the higher floor has shorter pipes and lower cooling capacity loss than system serving lower floors. That was why the COP of F7 system was higher than F5 and F1 system.
- The selection of oversized outdoor unit made the system always operating in low part load ratio region and led to low COP results. The system for Floor 4 was a typical example of oversize.

Besides the testing of system COP, the setting of indoor air temperature was also monitored. Some people tended to set it lower than 23 ℃ which led to low evaporating temperature of indoor units and caused the waste of electricity.

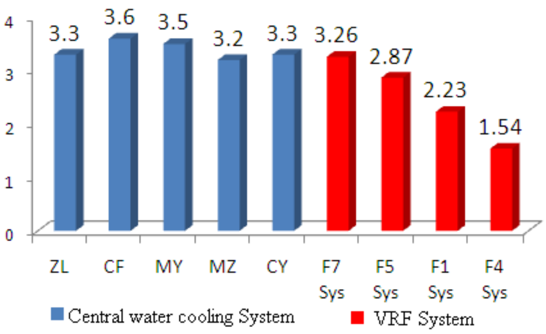





Tested hourly cooling capacity and Elec. Consumption of one VRF system in a working day



Tested COP - Part load ratio results of VRF systems in different floors



Average COP for cooling of office buildings in Beijing

Conclusion

This case study was very instructive on many points:

- The average COP for cooling of VRF systems ranges from 1.5 to 3.3 due to the difference of system structure and unit size. Compared with the COP of central water cooling system, a well-designed VRF system can be the same good, but others were relatively lower.
- The length of refrigerant pipes has a huge impact on the system COP. Long pipes will lost more cooling capacity and caused low COP. The position of outdoor unit and indoor units should be carefully considered to reduce the pipe length as much as possible. It's better to make room for outdoor unit in each floor so that all the units belonging to a system can be placed in the same floor, which has the shortest pipe length.
- The proper size selection for outdoor unit is very important. Oversized outdoor unit will make the system always operate in low part load ratio and cause low COP. The selection of outdoor units should make the system operate in the part load ratio region with high COP (55% to 80%) for as long time as possible.
- The performance of VRF system was influenced by human behaviors especially in the setting temperature of indoor units. A too low setting point will not only cause low COP of system but also influence indoor thermal comfort. A setting point of no less than 26 ℃ should be advocated from the consideration of saving energy.

Imprint

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Field monitoring
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Date of case study summary: July 2005

Literature

IEA-ECBCS Annex 48 website: http://www.ecbcs-48.org

IEA-ECBCS Annex 48

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).

Internet: http://www.ecbcs-48.org