Energy and cost savings with fresh air cooling systems

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Objekttyp: **Article**

Zeitschrift: **Comtec : Informations- und Telekommunikationstechnologie = information and telecommunication technology**

Band (Jahr): **83 (2005)**

Heft 6

PDF erstellt am: **10.07.2024**

Persistenter Link: https://doi.org/10.5169/seals-877160

Energy and Cost Savings with fresh Air Cooling Systems

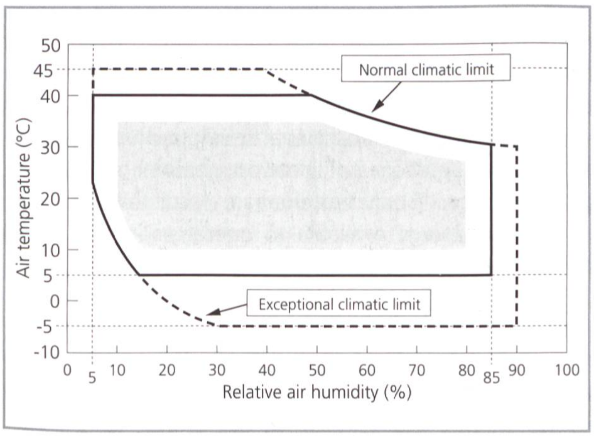
DOMINIQUE SINGY AND DIETER TÖBBEN **How to save energy and reduce capital and maintenance costs for network equipment cooling systems, while fulfilling climatic requirements? Simulations and trial results show that using solely fresh air to cool the network equipment at Swisscom Fixnet AG is feasible. Through the implementation of this cooling method annual energy savings of 45 GWh and a capital costs reduction of a factor 3 to 4 can be expected.**

The heat dissipation produced by network equipment has to be removed in order to keep the room temperature within safe limits, thus preventing equipment failures resulting from excess temperature. Until recently, the room temperature in telecommunications centres of Swisscom Fixnet AG was held at a nominal 24 °C, which was considered suitable for both equipment and humans. In 2001 the nominal room temperature was increased to 28 °C for the purpose of energy savings. Today, cooling is usually done using cooling systems combining chillers and free cooling. Free cooling is used during the cooler parts of the year, while chillers are used when outside temperatures exceed 12 °C. As the cooling systems currently in use at Swisscom Fixnet AG are rather old, require high maintenance and use a lot of energy, a replacement is needed. In this context, Swisscom Innovations, in collaboration with the engineering company Dr. Eicher+Pauli AG, has evaluated an appropriate cooling method for this purpose by considering

- current climatic requirements for telecommunications equipment,
- state of the art of cooling engineering,
- reliability,
- energy and environmental issues,
- cost effectiveness.

In the present article, we briefly explain the proposed cooling method and present the results of trials carried out in summer 2005.

Fig. 1. Climatic limits for normal (full line) and exceptional (dashed line) operating conditions, respectively, according to ETSI EN 300 019-1-3 Class 3.1. Exceptional operating conditions, i.e. climatic values between the full and the dashed lines, shall have a probability of occurrence of less than 1% and values outside the shaded area of less than 10%. See text for additional information.



Environmental Conditions for Network Equipment

The environmental class 3.1 of the ETSI Standard EN 300 019-1-3 [1] applies to network equipment used in telecommunications centres. ETSI (European Telecommunications Standards Institute) deals with the production of technical standards which apply to telecommunications equipment used throughout Europe. The allowed room temperature and humidity range for network equipment is shown in figure 1. According to this standard, the temperature may vary between 5 °C and 40 °C under normal operating conditions (solid line in fig. 1). Under exceptional conditions, e.g. cooling systems failure, the temperature is allowed to increase up to 45 °C (dashed line in fig. 1). Exceptional conditions may occur for 1% of the time at most. Under these conditions a reduction in equipment performance is allowed. However, there should be no irreversible failures once normal operating conditions have been restored [2].

Use of Fresh Air only for Cooling Network Equipment

Considering the typical annual outside air temperature and humidity distribution in the lower-lying areas of Switzerland and the allowed temperature and humidity range for telecommunications equipment according to figure 1, one can deduce that the use of fresh air cooling without chillers for the entire year is feasible provided the fans are correctly designed in order to prevent excess room temperatures on hot days in the summer, and to maintain suitable room temperatures in the winter. Telecommunication centres typically show a massive construction. Hence, the heat capacity of the building envelope is expected to contribute to the lowering of the peak room temperature on hot days. Based on this consideration, simulations of room temperature behaviour have been performed at various specific thermal loads, defined as the ratio of the thermal load to the floor area, for a typical telecommunications centre using fresh-air-only cooling. In these simulations, the fresh-air flow varies according to the outside air temperature. The maximum flow rate has been calculated

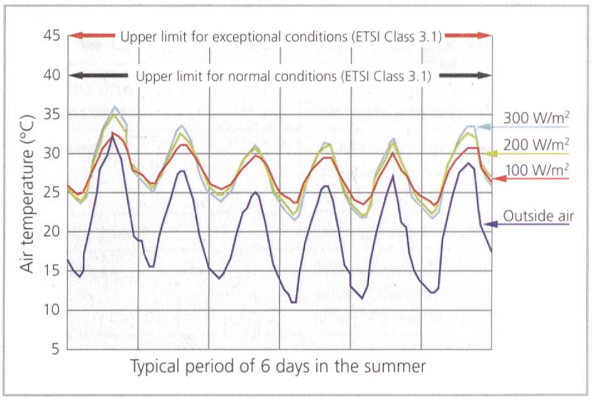


Fig. 2. Results of simulations of the room temperature behaviour at a typical telecommunications centre using fresh-air-only cooling for specific thermal loads of 100 (red line), 200 (green line) and 300 W/m² (light blue line).

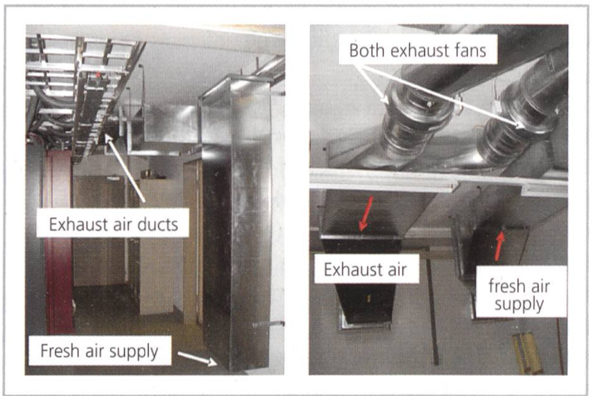


Fig. 3. Fresh-air-only cooling arrangement at a pilot site in Bern.

so as to keep the room temperature within 8 °C above the outside temperature, without considering the influence of the building. Minimum room temperature was set to 22 °C. The results for a typical period of 6 days in the summer are shown in figure 2. One can observe that even at the highest specific thermal load of 300 W/m² the maximum room temperature on hot days is kept below the upper limit for normal operating conditions according to ETSI Class 3.1. A safety margin is still available to support extreme outside temperatures, as experienced e.g. in the summer of 2003. The yearly distribution of simulated values shows that for most of the year, room temperature remains below 24 °C. Higher temperatures would occur during less than 20 % of the year. These results comply with previous investigations carried out at Swisscom Innovations [3]. In addition, from the simulations the relative humidity is expected to remain within the allowed range throughout the year.

Improved Comfort for Staff

Staff presence at sites with network equipment is restricted to maintenance. By cooling with fresh air only, for most of the year the room temperature will be kept between 22 °C and 24 °C. On hot days in summer, people entering the building will experience a room temperature comparable to the outside temperature. The indoor air movement caused by the fans, as well as the lower temperature of walls and floor will add to a feeling of improved comfort. Such conditions are expected to be more comfortable than the current situation, where the room temperature is specified at a nominal 28 °C throughout the year.

Proposed Cooling System

The proposed cooling system basically consists of two single-stage exhaust fans located at the top of the room (see fig. 3). Each fan provides 50 % of the rated air flow volume. Should one fan fail, more than half of the cooling power would still be available (over 50 % redundancy). If lower system availability is required, only one fan providing 100 % of the rated air flow volume can be used. The rated air flow volume is set to 0.1 m³/s per 1 kW of required cooling power. The first fan is switched on at 24 °C and switched off at 22 °C; the second one at 26 °C and 24 °C, respectively. Rigid or flexible air ducts are mounted above the cabinets so that the exhaust air from the cabinets is directly driven towards the exhaust aperture (hot spot exhaust). Outside air is supplied to the room through an aperture in the outdoor facade. The room temperature is normally monitored at a height of 1.65 m (±0.15) above the floor and at least 50 cm away from the cabinets. This cooling method is planned for specific thermal loads up to 500 W/m². For thermal loads <50 W/m², no fans are needed. In this case, two apertures in the outdoor facade are appropriate for sufficient fresh air supply.

Advantages of the new Cooling Method

Higher reliability of the new cooling system compared to usual systems with chillers can be expected due to its simplicity. The system can easily be extended. On-site maintenance is reduced. The cooling system capital costs can be strongly reduced. According to current trial results, a coefficient of performance (COP: ratio of the effective cooling power to the power needs of the cooling system) of more than 20 can be reached using fresh-air-only cooling. Moreover, constraints for using refrigerants are expected to become more and more severe in the future. According to the new Swiss Ordinance on risk minimisation related to chemical products, regular sealing controls on stationary cooling systems using more than 3 kg of ozone depleting refrigerants are mandatory at least once a year. Such controls generate additional maintenance costs. In addition, new cooling systems must from now on be approved by the Swiss control authority. Only systems using refrigerants without ozone depletion potential are exempt from the new Swiss Ordinance. Such systems exist today, but are not yet very widespread. The elimination of refrigerants altogether is therefore the preferred solution. Fresh-air-only cooling complies with this demand.

Telecommunications centres are equipped with batteries or generator sets to supply network equipment in case of power outage. If only batteries are used, there will not be enough energy available to operate cooling system chillers. However, if fresh-air-only cooling is used, it will be possible to use the available battery capacity to supply at least one fan at the sites with high thermal loads during an outage, because of its low energy consumption. If necessary, the battery capacity can be adapted to this additional power need.

Trials at Pilot Sites

Prior to the release of the proposed cooling method, trials were carried out at various pilot sites in summer 2005. As an example, the results of temperature measurements at one site in Bern for the representative period of June 20 to 30 are shown in figure 4. The thermal load at this site was 270 W/m^2. Temperature sensors were positioned in the aisle between cabinets at heights of 10 cm, 1.65 m and approx. 2.25 m above the floor. The second and third positions correspond to the usual reference room temperature position and the cabinet height respectively. Temperatures were measured every 15 minutes. Outside air temperature data were provided by the Swiss national weather service, MeteoSwiss. The measurements show that the maximum reference room temperature reached 32 °C, while the outside temperature reached a maximum of 34 °C. The maximum air temperature at the height of the cabinets was close to the outside temperature on the warmest days. These results confirm the predictions from simulation. The lower room temperature measured on hot days in the summer reflects the impact of the hot spot exhaust which was not considered in the simulations. This exhaust keeps the room temperature 5 °C below the air temperature in the exhaust duct on average, since most of the heat produced inside the cabinets is directly removed from the room, thus preventing equipment and surroundings from further heating up. The higher the specific thermal load is, the larger the impact of hot spot exhaust will be. Similar results were achieved at other pilot sites.

All the measured room temperature values in summer 2005 remain within the allowed temperature range according to ETSI Class 3.1. Moreover, a sufficient safety margin is still available in the event of failure of the fans. In addition, measurements at one pilot site show that the relative humidity never exceeded a value of 60 %. This result confirms the predictions from simulation.

The cooling fans are consuming less than 5 % of the energy needed to operate the network equipment. A drastic reduction of the energy consumption can therefore be achieved with the new method. The indoor climate generated by the new cooling system on hot days was judged comfortable by staff members working at the pilot sites.

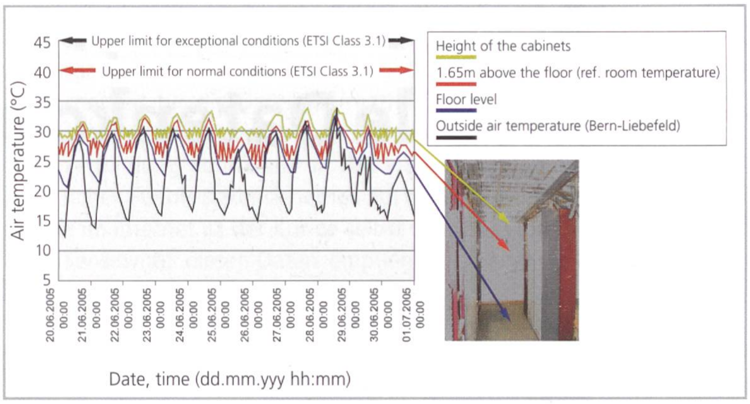


Fig. 4. Air temperature profiles measured at various heights above the floor in summer 2005 at a pilot site using fresh-air-only cooling in Bern. The rapid temperature changes of about 2°C are correlated to the switching on/off of the second fan.

Improved Reliability

Environmental conditions have a significant effect on the reliability of electronic equipment. A typical example is the component failure rate: It normally increases with rising temperature, with the average temperature being the determining parameter [4]. Use of fresh-air-only cooling all year round will result in higher room temperatures in the summer. However, these temperatures will be over-compensated by lower room temperatures during the rest of year, thus leading to a yearly average room temperature below 24 °C. The average failure rate is therefore expected to be lower than with today's nominal temperature of 28 °C specified year-round.

Conclusion

High capital and maintenance cost reduction as well as high energy savings can be achieved through the use of fresh air only to cool the network equipment year-round. Results of trials carried out at various pilot sites in summer 2005 show that by using this new cooling method, the room temperature on hot days is kept below the upper limit of the allowed temperature range for normal operating conditions according to the ETSI Class 3.1. The peak room temperature on hot days is strongly reduced through a hot spot exhaust and through the heat capacity of the building. A safety margin is still available, if a failure of fans should occur. The new method is environment-friendly because refrigerants are eliminated. This method has been adopted at Swisscom Fixnet and will be implemented in the future by replacing existing cooling systems. A reduction in the energy needed for cooling of 45 GWh per year is expected after full implementation. The capital costs will be reduced by a factor 3 to 4. If a heat demand exists at some sites, it is possible to recover heat from the exhaust air and to use it in conjunction with a heat-pump. Because of the encouraging trial results, possible use of this cooling method in data centres should be investigated in the future. This scenario is realistic since the climatic specifications of new servers available on the market nearly comply with those of telecommunications equipment. ■

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Acknowledgements

The work described in this article was carried out in the context of the project MISTRAL on behalf of Pascal Gasser, Head of General Infrastructure Platforms at Swisscom Fixnet AG

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