- White Paper -

Efficient data center air conditioning

Dynamic Free Cooling®

Contents

1. Abstract

Increasing energy costs and limited resources of available electricity are driving the data center industry toward energy-efficient technical equipment. Dynamic Free Cooling® is a control concept for air conditioning systems in data centers, combining hybrid indirect free cooling precision air conditioning units, fan-speed-controlled dry coolers, and speed-controlled central pumps into a highly efficient precision cooling system. All system components are centrally controlled to minimize overall energy consumption depending on the ambient temperature and the room load conditions.

2. Why Do I Need an Energy-Efficient Cooling System?

There are two major reasons for using an energy-efficient precision cooling system for your data center. Firstly, in addition to the energy consumption of the servers, etc., themselves, air conditioning consumes the largest proportion of the energy used in data centers. This share can be greatly reduced by using modern air conditioning systems with free cooling.

Secondly, electrical power is becoming a scarce resource, and it should be used to maximize the use of the servers rather than wasted unnecessarily on powering cooling equipment.

Alongside reduced costs and more efficient power management, there is also always an argument for “green” data centers with a low carbon footprint, made possible by using energy-efficient cooling systems. In addition, low operating costs can provide a competitive advantage, especially for data center operators who rent space in the data center or in individual racks.

3. Energy Consumption of Air Conditioning Systems in Data Centers

Data centers need air conditioning systems to remove the heat generated by the servers and other heat sources. The air conditioning systems need to be reliable and available 24/7 with built-in redundancy. Temperature, humidity, and air cleanliness must match the IT equipment manufacturer’s specifications.

There are various air conditioning systems available, but all of them require significant electrical power to run the fans, compressors, and pumps. Fans in the CRAC units within the room circulate the conditioned air to transfer heat from the IT equipment to the CRAC units.

Compressors increase the temperature and pressure of refrigerants to transfer the heat to the atmosphere at high outdoor temperatures. In chilled water or cooling water systems, pumps transport the water that has absorbed the heat out of the building. The refrigerant compressor consumes the largest amount of electricity in the air conditioning systems.

4. Reducing the Energy Consumption of Air Conditioning Systems in Data Centers

Data center air conditioning systems are usually oversized by design for further growth, redundancy, and as a safety factor. The additional air conditioning plant can be used to reduce overall energy. This is also recommended according to DIN EN 50600. Standby units can be used to distribute the airflow to all units, leading to significant power savings. By doing so, the heat exchanger surface of the standby units is also used, thereby increasing the efficiency of the total system.

This is also the case with the CyberRow series of cooling units with DFC® control. With high or low heat loads, the heat is dissipated via all devices, including the standby devices, automatically minimizing the energy requirement of the cooling system.

Logically, the mechanical refrigeration in the air conditioning system is only required when the outside ambient temperature is higher than the internal temperature of the data center. If the ambient temperature is low, there is no need for the refrigeration compressor to operate. The heat in the room can easily be transferred directly to a water/glycol solution and pumped outside the building, where the heat is then transferred from the water/glycol solution directly to the ambient air. Ethylene glycol is added to the water to prevent the dry cooler from freezing in the winter.

The temperature of the glycol has a major influence on the efficiency of the air conditioning system. The higher the glycol temperature, the lower the CRAC unit's cooling capacity. However, crucially, the number of hours per year in which the system runs in free cooling mode increases dramatically. These circumstances can easily be taken advantage of by the DFC® system, resulting in reduced air conditioning running costs.

6. The Air Conditioning System with DFC®

The system described in this article consists of hybrid CRAC units located in the data center, dry coolers located outside the building, and pumps that circulate the glycol in a closed hydraulic circuit between the CRAC units and the dry coolers.

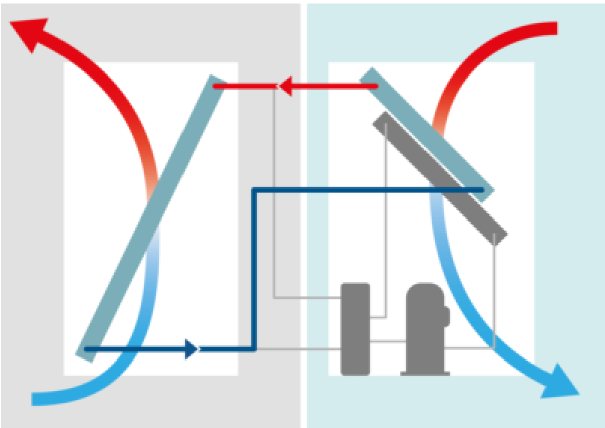

Figure 1: Free cooling

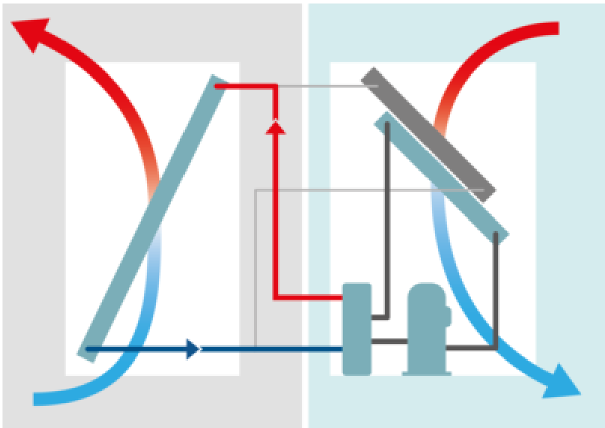

Figure 2: Compressor cooling

The hybrid CRAC units consist of speed-controlled EC fans for air circulation in the data center, a small, closed refrigerant circuit with scroll compressors, and an air-to-glycol heat exchanger for free cooling operation. Due to the decentralized refrigeration and the very small refrigeration circuits made possible by it, only a small amount of refrigerant is required. The sharp rise in refrigerant prices due to the F-gas Regulation has therefore had very little impact on the cost of an indirect free cooling system with DFC® control.

The dry cooler consists of a glycol-to-air heat exchanger coil with variable-speed EC fans for circulating ambient air through the heat exchanger coil. The central inverter-driven variable-speed pump circulates the glycol between the CRAC unit and the dry cooler and out of the data center. All components involved in the air conditioning process are controlled only by the microprocessor in the CRAC units, as well as outside ambient air sensors and return air sensors in the air intake of the CRAC units.

7. Dynamic Free Cooling® – How Does it Increase Efficiency?

There are various elements that make up the Dynamic Free Cooling® system and make it as efficient as it is. The most important elements are described below.

7.1. Dynamic Water Temperature Control

Standard indirect free cooling systems operate with fixed water or glycol temperatures for a regular compressor operating mode of, for example, 35°C at high ambient temperatures and approximately 7°C in free cooling mode at low ambient temperatures.

The period of usable free cooling is very limited, as there are only relatively few hours per year in which the ambient air is around 3°C or lower and cold enough to produce glycol of 7°C. By means of DFC®, the glycol temperature is not fixed, but is fully dynamic depending on the requirements of the system. Why is this? It is important to understand that this system operates like a chilled water system in free cooling mode. The cooling capacity of chilled water systems depends on the water temperature: The higher the water temperature, the lower the cooling capacity. While this may sound negative, the DFC® control in fact takes advantage of these circumstances, especially when the data center operates at part load.

A data center operating at full load requires a water temperature for free cooling of around 10°C. Water at this temperature can be produced by the external dry cooler with ambient temperatures of up to 7°C. The same data center operating at a part load of 60% also only requires 60% cooling capacity. The air conditioning system in free cooling mode can already produce this 60% cooling capacity at a much higher glycol temperature of 16°C, and this glycol temperature can be achieved with an ambient temperature of 13°C. What does this mean for the period of free cooling per year? In London, 18% = 1,580h per year are below 7°C, while 55% = 4,770h per year are below 13°C (Figure 3). This means that there are an additional 3,190 hours or 133 days per year that can be used for free cooling. Conventional free cooling systems still work in mixed operation or with 100% compressor cooling during this time.

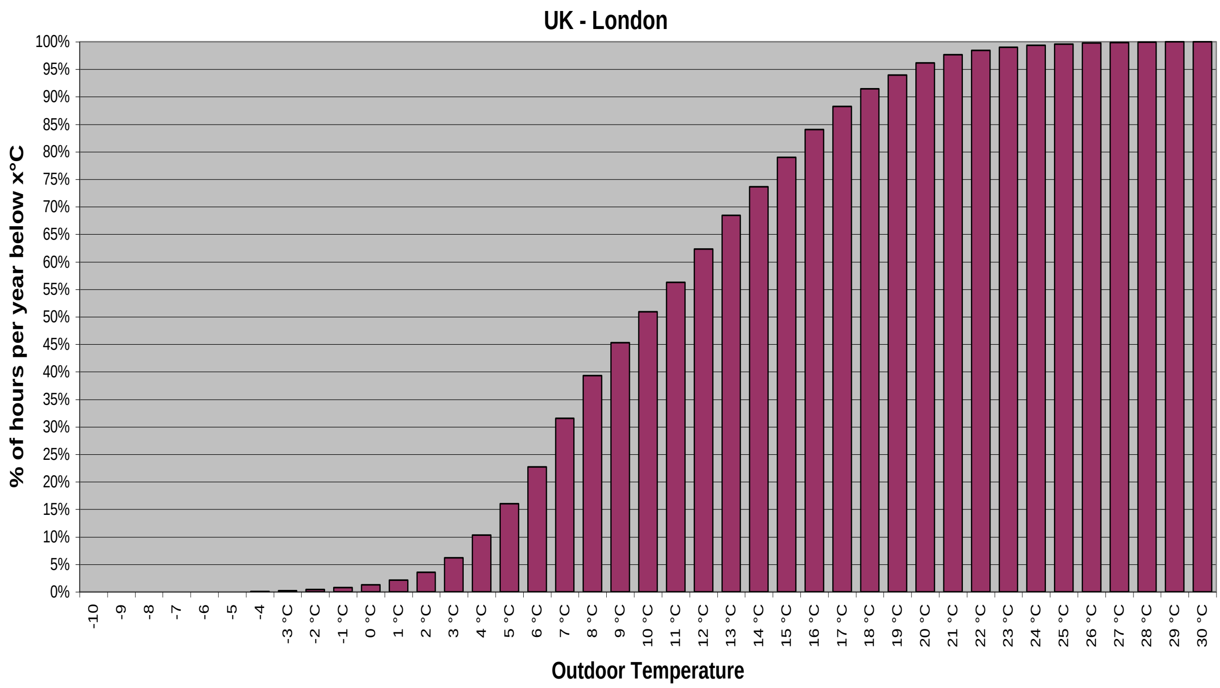

Figure 3: London, hours below x°C per year

7.2. Free Cooling Standby Management

Most data centers are designed with standby redundancy to cater for CRAC unit maintenance or failure. To save energy, the standby units are designed to be sequenced off as they are not needed to handle the cooling load. By means of DFC®, the CRAC units operate in free cooling mode in a new, different way. The use of high-efficiency EC fans enables automatic control of fan speed. Fan laws dictate that air volume is directly proportional to fan speed and that fan power is a cube of the fan speed (Figure 4). Therefore, by running the standby CRAC units at reduced speed (air volume), the overall fan power consumption is drastically reduced. It is more energy efficient to run all units, including the standby CRAC units, at a lower speed than to shut off or sequence off the standby units. This technique also provides a more even and predictable air distribution throughout the raised floor.

If the DFC® logic is combined with the regulation of the air volume depending on the pressure in the raised floor, the air volume is adjusted according to demand in addition to the uniform air supply.

DFC® controls the CRAC units in free cooling mode in this new way, resulting in significant cost savings on fan power. Should a DFC® controlled CRAC unit be switched off, the remaining units ramp up their fan speed automatically to ensure full air circulation.

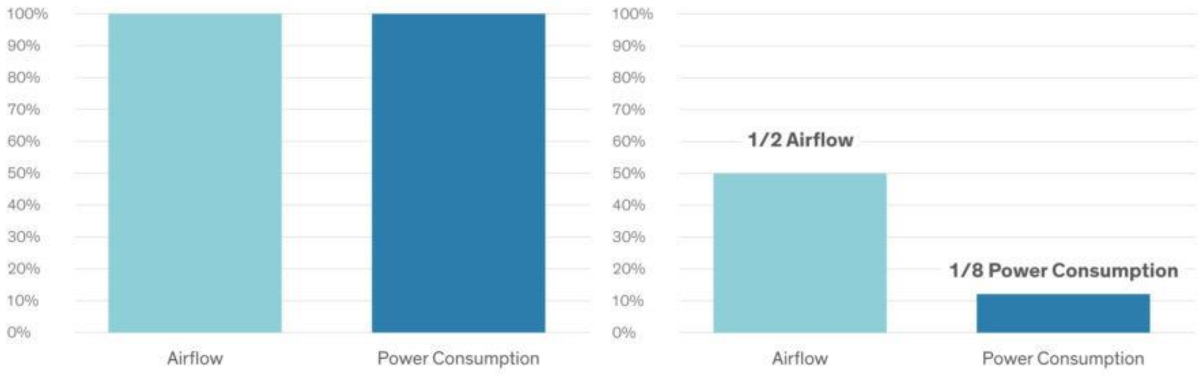

Figure 4: Standby management and Square-Cube-Law

7.3. Indirect Free Cooling

Dynamic Free Cooling® is an indirect free cooling system. Indirect free cooling (Figure 5) uses glycol as a heat transfer medium between the data center air and ambient air at low ambient air temperatures. There is no need to introduce ambient air directly into the data center, which therefore preserves the data center's vapor seal. A very small amount of fresh air is required in the data center to meet the local code regulations for ventilation standards.

Direct free cooling systems (Figure 6) use ambient air, which must be preconditioned and pre-filtered before entering the room. Ambient air quality and conditions normally forbid the use of direct free cooling. Induced smoke can activate fire suppression systems, dirty air requires a high degree of filtration and a very regular (not to mention expensive) filter maintenance program, and low specific moisture levels in winter require a huge amount of costly pre-humidification.

The air conditioners in the data center are only connected to the heat rejection units outside the building by piping. The building envelope does not have to be interrupted by large openings for supply and exhaust air, as is required with direct free cooling systems, and this can also have an impact on the safety and fire protection properties of the building

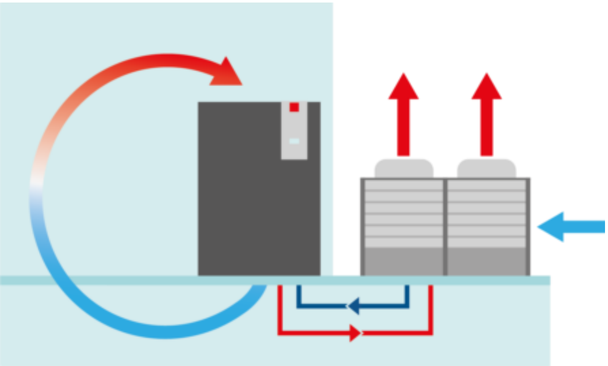

Figure 5: Indirect free cooling

Figure 6: Direct free cooling

7.4. Dynamic Component Control

There are four major energy-consuming components in the air conditioning system: The compressor in the CRAC units, the fans in the CRAC units, the central pump, and the fans on the dry cooler outside the building.

Dynamic Free Cooling® controls these components depending on the ambient temperature and the room load conditions. The microprocessor controller analyses the ambient air temperature and the difference between actual and design room temperature to optimize the components in the CRAC units in order to reduce energy consumption while still maintaining room conditions. The key focus is to minimize the running time of the components using the most energy, i.e., the compressors.

The next priority is to control the remaining components – the CRAC unit fans, the dry cooler fans, and the central pump – to ensure that the total absorbed power is kept to a minimum.

7.5. Optimized Casing Design

The CRAC units used for the DFC® system are optimized for high efficiency. The airflow pattern and internal components are designed to minimize air resistance. For the same reason, the casing itself is enlarged compared with units without free cooling. These design measures reduce the fan power by up to 40%. New models with the fan section under the raised floor further reduce the fan power consumption.

7.6. Dual 2-Way Valve System

The hydraulic system is designed with the use of two 2-way valves in such a way that the glycol quantity circulating in the system absorbs the largest possible amount of heat in the CRAC unit, whether in free cooling, mix, or compressor cooling mode. The glycol quantity circulating in the system is reduced and the required pump power is minimized.

8. Dynamic Free Cooling® – How Much Can Be Saved?

Use of Dynamic Free Cooling® can lead to savings of up to 60%. These savings depend on several factors, including the geographical location (annual temperature profile), the comparison system, the standby quantity, the design room temperature, and the percentage of actual IT equipment cooling load installed compared with the peak design. Calculation software to compare different systems, taking into consideration all the above variables, is useful in making a selection. Manual calculations are possible but complex, and it usually takes several days to make just one comparison.

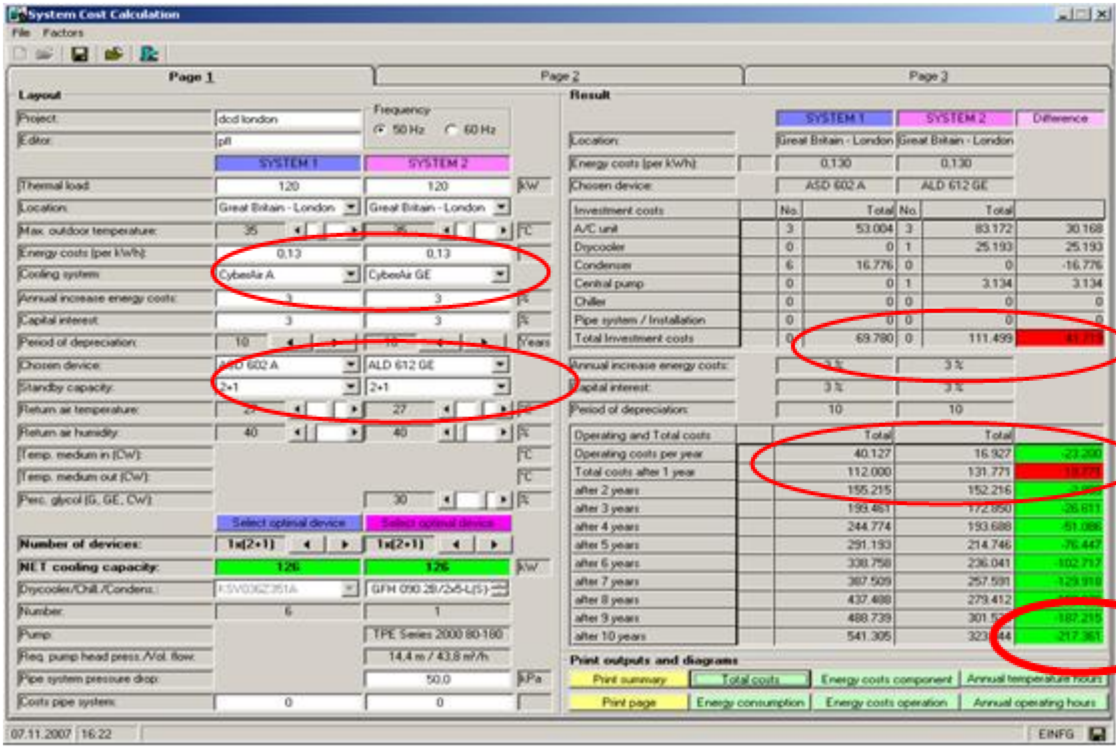

Figure 7: Example of software for system comparison

9. Dynamic Free Cooling® – What Does it Cost and What is the Payback Period?

The capital cost for a Dynamic Free Cooling® system compared with a basic air-cooled system can be up to 50% more. However, the savings on operating costs are huge; typically, the payback period is between less than 1 year and 3 years.

10. Addendum

The first version of this white paper was published around 10 years ago, and the time has now come for an update. A lot has changed in the past decade, yet Dynamic Free Cooling® remains one of the best control concepts for extremely efficient indirect free cooling systems.

Since the introduction of Dynamic Free Cooling®, the developments in terms of precision air conditioners have been non-stop. Efficiency has been further optimized and what is physically feasible has been exploited in the best possible way.

Models with controlled compressors reduce energy consumption in partial load operation or mixed operation even more than was previously possible with on/off compressors.

Fan units in the raised floor permanently reduce the energy consumption of the fans in the precision air conditioning units. This ensures optimum air flow with minimum resistance through the air conditioners and from the air conditioners to the raised floor.

The Stulz CyberRow range of row cooling units has been extended to include models with indirect free cooling – currently the only ones of this kind in the world – meaning that Dynamic Free Cooling® is now also possible with row cooling units in addition to perimeter cooling units.

Another now widely used control concept, the air volume control of precision air conditioners depending on the pressure in the raised floor or in the cold aisle containment can also be used together with the Dynamic Free Cooling® control. The circulating air volume is thus automatically adjusted to the demand.

The F-gas Regulation has now come into force. The quantities of R410A and R407c refrigerants, as well as other refrigerants in Europe, are being limited, and the costs of refrigerants are rising rapidly. The Dynamic Free Cooling® system with Stulz CyberAir GE or GES units contains very small refrigerant circuits, and the amount of refrigerant required in relation to the cooling capacity of the system is extremely low.

DIN EN 50600 has also been published. Clearly defined security concepts for high-availability data centers can all be implemented with the Dynamic Free Cooling® system, an invaluable advantage over systems that are installed outside the data center, for example.

Finally, the ASHRAE TC 9.9 has been updated. Server inlet temperatures should be in the 18°C to 27°C range. With the Dynamic Free Cooling® concept and a return air control system, the supply air/server inlet temperature is able to move into the range recommended by ASHRAE at partial load. The higher the server inlet temperature, the higher the outdoor temperature at which the system can operate in free cooling.

About the Author:

Benjamin Petschke was born in Germany in 1969. After studying physics, he joined Stulz GmbH in 1996 and began work in the R&D department. In 1998, Benjamin moved to the export department, where he held various positions. With more than 22 years' experience in the data center cooling industry, Benjamin now takes care of multiple product lines as a member of the product management team, with specialisms in data center cooling systems, energy savings, and acoustics. Benjamin works closely with the Joint Research Centre of the European Commission for the Code of Conduct on Data Centers as part of the Best Practice section, and he also worked with the German DKE to develop the DIN EN 50600, Information technology – Data centre facilities and infrastructures. Benjamin has authored white papers on subjects including best practice for data center cooling and indirect free cooling with dynamic control logic.