Data Center Cooling Efficiencies

A TEAM Companies White Paper

March 2009

Data Center Cooling Efficiencies

Table of Contents

Chilled Water Systems

Chilled Water Systems …… 3

Air Distribution Systems

Air Distribution Systems …… 5
Hot Aisle / Cold Aisle …… 6
Managed Return Airflow …… 7

Virtualization

Virtualization …… 8

Executive Summary

Data center cooling solutions are comprised of many complex variables that when configured ineffectively, can sharply increase the total cost of ownership and have a negative impact on the environment at the same time. This paper encompasses many different cooling systems, and highlights ways to economize them from equipment and distribution, down to cabinet and server level configurations.

TEAM companies

800 - 728 - 8326

Introduction

The Environmental Protection Agency (EPA) reports that energy usage in data centers across the country doubled from 2000 to 2006, and is expecting the number to double again by 2011. As of 2006, data centers roughly accounted for 1.5 percent of all electricity consumption, and this figure will climb to an estimated 3 percent by 2011.
A 2008 Fujitsu study published in their Scientific and Technical Journal revealed that "IT equipment generally consumes 45% of all power, while HVAC equipment consumes nearly the same at 40%."

> *"Cooling resources consume almost all of the non-IT power in 85% of Data Centers."*
>
> Source: *HP Data Center Cooling Strategies Technology Brief*

These percentages are alarming when considering that coal-fired power plants, the single greatest contributors to green house gasses and global warming, are projected to continue as the dominant source of electricity generated through 2030. Couple that with the exponential growth of data center power consumption and it makes for a profound impact on the environment.

Data center cooling systems typically require almost as much energy as the entire IT load or more. Rising energy costs, inflating computing demand and high density IT equipment, are driving datacenter owners and operators to realize that finding greener technology solutions to maximize infrastructure efficiency, minimize their carbon footprints, and lower total cost of ownership is their top priority.

Chilled Water Systems

Taking the energy focused approach on cooling equipment configuration begins with the size of the datacenter and amount of critical load. If the facility is large enough to justify the cost of a chilled water plant, then a high efficiency system centered on centrifugal chillers should be designed. Centrifugal chillers currently offer the highest efficiency and reliability for data centers while offering the smallest physical footprint.

Chillers use refrigerant to take heat out of a water loop. The heat comes from inside the data center, is discharged to a second loop going outside and rejected by a cooling tower.

Chillers are by far the largest consumer of power in the data center. So when owners and operators look into improving efficiency in the facility, chillers are the first place to start. In these cases, the engineer should look at a base plant design that uses the minimum chiller efficiency required to meet local energy codes. Once the requirement is met, the chiller system will be evaluated for efficiency based on payback and backup power requirements.

The IPLV / APLV rating keeps track of real world chiller energy performance by recognizing that chillers run beneath their designed full load value and so the kW/ton calculation is done from four design loads instead of one: 100%, 75%, 50%, and 25%.

Source: *York International Corp. HVAC&R Engineering Update*

Chiller efficiency ratings are most often expressed by their kW/ton full load efficiency rating. However, this rating is only valid when the chiller is operating at full load and as critical load demand on the chiller falls below 100 percent, the operating efficiency does as well. The best way to determine efficiency for a chiller is to look at the integrated part load value / application part load value (IPLV/APLV).

After the appropriate chiller is selected, the next step is evaluating how adding Variable Speed Drives (VSDs) can further increase the efficiency of the chiller by modulating load over the course of an ambient season of operation. A recent TEAM Companies cooling study showed the following:

Chiller System Description	Annual Energy (kW-hrs) =	Annual Chiller System Operating Cost
Standard Chiller to Meet Local Code	3,780,644	$241,259
High Efficiency Chiller	3,203,733	$204,406
High Efficiency Chiller with VSDs	2,728,388	$175,109

This example shows us that choosing a high efficiency chiller with VSDs resulted in an annual energy savings in excess of 1,000,000 kilowatt-hours. This 27% increase in efficiency amounts to a cost reduction of $66,000 per year, a significant savings, but more impressive will be the next phase of the data center, which will utilize high efficiency chillers with twin state-of-the-art magnetic bearing compressors and VSDs. The additional annual savings from the new machines is estimated to bring total efficiency to 34%, dropping energy usage an additional 250,000 kilowatt-hours and saving an extra $16,000 annually. Local utilities often help to offset initial costs by providing rebate incentives to become more efficient.

Air Distribution Systems

There are two main forms of air distribution systems, a Constant Air Volume (CAV) system and a Variable Air Volume system (VAV). CAV systems, which provide little control, always retain the same airflow while the system is running and can be very wasteful. VAV systems change dynamically in response to the critical load to provide cooling when it is needed and drastically reduces energy costs as a result.

In VAV systems, dampers restrict or relinquish air flow to the critical load when there is a change in cooling demand. Fans are paired with Variable Speed Drives (VSDs) to control their fan speed to ramp up and down based on return air temperature throughout the day to economize fan power. In addition, chilled water valves inside the air handler can also be throttled to change supply temperature in response to the critical load, creating a Variable Volume Variable Temperature (VVVT) system.

VVVT systems can be the most efficient because they economize chiller load and fan power simultaneously by changing both the temperature and volume of the supply air to provide optimal load responsiveness. When incorporating VVVT systems in a data center, it is necessary to use the appropriate sensors and controls to monitor each cabinet individually. Care must be taken to make sure that all critical components can still reject their heat appropriately. Aside from the general aspect of the VVVT system, there are many ways to increase efficiency with air distributions systems on the component level as well.

The fans, belts, ductwork and filters selected for the system can also make an impact on reducing energy. Housed centrifugal fans and plenum fans with airfoil blade configurations are among the most efficient, as opposed to axial fans, which may be less expensive but seldom work for data centers because they are unable to efficiently handle static pressure in the system.

V-Belts are the standard belts found throughout the industry, but it is common to see efficiency loss in a worn belt from slippage, either due to relaxing or worn down surfaces. “Using a cogged V-Belt to prevent that slippage can increase efficiency or using a synchronous belt, which transfers power by using teeth as opposed to friction, to completely remove slippage and tension issues altogether, achieve efficiencies up to 99%.” (Source: *Energy Star Air Distribution Systems, Revised April 2008*)

Duct work comes in two shapes: square and round. Although square ductwork is commonly seen, spiral ductwork can be more efficient for data centers because they have a lower pressure drop and have optimal thermal transfer due to having a smaller surface area. Spiral lock seams reinforce the ductwork to make it more durable and it is usually less expensive, reducing cost on cooling and implementation.

Filtration is last, but certainly not least. Filters play one of the most important key roles in the air distribution system. Large drops in pressure across the filter can absorb a staggering amount of fan power. The key to efficient filters depends on how well they remove particulates from the stream without slowing down airflow. Having a reliable filter replacement program in place with efficient filters prevents unnecessary stress to the fan and duct system, reducing overall wear and tear and energy costs.

Hot Aisle / Cold Aisle

Hot Aisle / Cold Aisle CAV cabinet configurations align with the cold air intake facing one aisle while the hot air return faces the other. Air is typically brought up through a raised floor, passes through the cabinet and is exhausted out the backside where a computer room air conditioner (CRAC/CRAH) unit takes in the air and recycles it. Often, those CRAC units must be over-provisioned in order to compensate for the bypass airflow that mixes hot and cold air together.

Although this particular configuration was popular a few years ago, even becoming the standard for a while, times are changing. Data center owners are realizing that with the rising density of servers, the efficiency these systems once provided is dwindling and becoming more difficult to manage.

However, Computational Fluid Dynamics (CFD) has come a long way to overcome the inherent shortcomings and help put energy savings back in the hot aisle/cold aisle systems. CFD uses numerical methods and algorithms to analyze and solve complex air flow problems. Using CFD models can help determine how to control air distribution through the space effectively and prevent bypass airflow. CFD calculations can also determine how changes in equipment layout will impact cooling resources and where possible points of failure in air flow may exist.

Managed Return Airflow

Individually ducted cabinets can be a more efficient method than hot aisle / cold aisle configurations, because there is no mixing of hot air and cold air inside the data center. With this CAV system, the cold air is brought in from overhead, and the hot return is ducted back to the main air handler. Distribution of cold air through the data center no longer matters because the air must flow out through the rack space, leaving no wasted air, no bypass airflow and no need for over-provisioning like the hot aisle / cold aisle system. This ducted approach allows the potential for higher power and higher density servers to be cooled by removing the dependency on the amount of cubic feet per minute (CFM) through a floor tile. This eliminates the need for a raised floor.

Eliminating over-provisioning by separating the hot from the cold air means that air no longer has to be supplied at 55 degrees to overcome the air mixture. The supply only needs to be the same temperature as the lowest equipment inlet temperature. If the lowest required inlet temperature is 70 degrees, then the supply air can also be 70 degrees. Higher supply temperatures translate into drastic improvements to chiller system efficiency.

Virtualization

Virtualization of computing resources allows multiple virtual computers to be combined and shared from a central server. In terms of cooling, instead of having 10 servers running at a steady load, regardless of whether they are in use, all 10 servers are combined into a single server that grows to meet workload demand. The computing resources which are not used are put in standby, to minimize energy consumption and maximize cooling.

Hot Aisle / Cold Aisle cabinet configurations can run into problems with virtualization when workload demand causes resources to come out of standby and begin fluctuating heat loads within the data center. These fluctuations can cause the airflow in the data center to change dramatically as the heat loads shift from cabinet to cabinet throughout the day, creating temporary hot spots. One method data centers use to try to combat virtualization hot spots is to install in-row CRAC units that respond to abnormally high temperatures and provide extra cooling.

In the past cabinets used only used about 2 kW each and emitted roughly 40 Watts of heat per square foot; the new high density racks will use 10 to 25 kW and give off up to 500 Watts per square foot. A failure within the cooling system once afforded greater response time, whereas now temperatures can quickly get out of control.

Data centers that follow best practices will see a 1 to 1.5 percent reduction in chiller plant energy use for every 1 degree increase in the chilled water loop temperature, or a 5 to 35% energy use reduction.

- ***Thermal News, Winter 2008***

New power configuration options with server processors allow the server to deal with a failure by throttling back all CPUs to give off minimal heat, scaling down resources to keep the IT Load cool until the failure can be resolved.

- ***AMD White Paper on Power and Cooling in the Data Center***

Conclusion

Datacenter cooling systems have several key components that can be economized individually to provide a more streamlined energy efficient system as a whole. The importance of examining every link in the chain and following EPA best practices is the only solution to truly reduce overall energy consumption. By making “green” changes to traditional cooling systems, data centers can yield up to a 70 percent improvement in infrastructure energy efficiency, significantly decreasing carbon footprints and ultimately lowering total cost of ownership.