Data Center Meltdown - Gone in 60 Seconds

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60 seconds is about the time it takes for a 10 kW (kilowatt) cabinet server load in a data center to heat up, initiate a self-protective shut down and cause immeasurable loss of revenue and revenue opportunity as a result of lost data. As much as 22.3 percent of all outages in a data center are caused by servers overheating and shutting down on their own, according to an April 2007 research study conducted by Aperture Research Institute. This is neither fiction nor an incident reserved only for the ultra high density data centers currently under construction. Self-protective shut downs due to high temperature in the server are very common among small to large data centers and computer rooms and typically occur during the event of a power outage. In these instances, the uninterruptible power supply (UPS) continues to provide uninterrupted power, but the cooling systems do not.

Active Power, Inc., has developed the only commercially available emergency cooling system based on mature thermal and compressed air storage (TACAS) technology.

CoolAir combines TACAS technology in a proprietary manner to produce backup power during an electrical disturbance while simultaneously discharging cold air as a by-product of its operation. To produce the cold air, the product uses a turbine fed by compressed air rather than batteries.

Powered Server - That's Not Cool

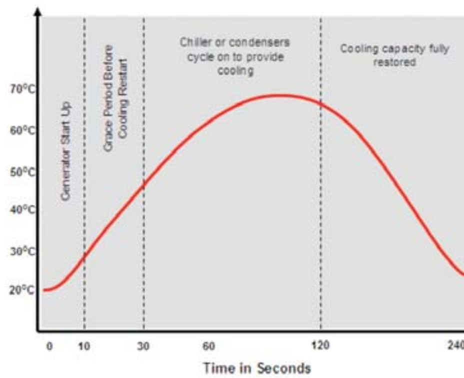
The UPS is tasked with feeding the server equipment conditioned and uninterrupted power. Unfortunately, it is not practical to run the data center cooling system off the UPS for a few different reasons:

- A typical cooling system in a data center consumes as much power and sometimes more than the server equipment it is protecting.
- The motor load characteristics of the outdoor chiller or condensers caused by the constant on/off cycling leads to significant step-loads that can trip a UPS and drop the remaining load.
- Cost usually prohibits the cooling system to be on an UPS due to the additional and possibly oversized UPSpower required.

Larger data centers typically have a fuel-fired generator coupled with the UPS system to allow for continuous operation during events where main utility power is unavailable for several hours or days. Where generators are available, the cooling system will typically be backed up to that. Generator or not, the result is similar; while the server load is kept up and running during a power outage by the UPS, the cooling system will fail.

Even with the generator restoring critical power in eight to 10 seconds, it takes significantly longer to cycle chillers or condensers back on. In simple terms, this process can be like starting from zero mph in the 4th gear in your car - not a good idea.

In fact, it can take as much as 20 to 30 seconds from the time power is restored by the generator until the cooling system receives the start signal. This is to avoid intermittent voltage drops and to ensure the generator is ready. Depending on the number of chillers or condensers in the facility, each will cycle on one by one until all are running at full capacity.



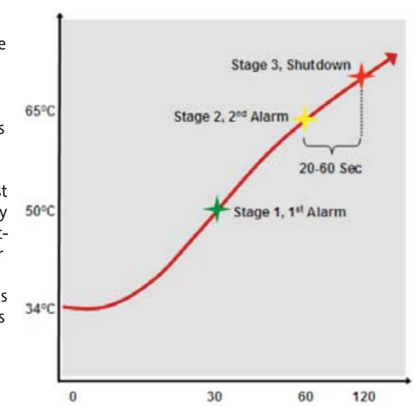
This process can take one to two minutes depending on the size of the system - all of which happens while the servers are powered and humming away without cooling. Unfortunately, the 10 kW blade server cabinet would have called it quits at 60 seconds.

Self-Protective Server Shut Down

The need for cooling has reached a point where businesses no longer count in hours or minutes of runtime without cooling, but in seconds. A typical rack-mount server features an embedded thermal management system. The system ensures the server does not sustain permanent damage in the event of rapid temperature increase.

ASHRAE (American Society of Heating, Refrigerating and Air Conditioning Engineers) Technical Committee 9.9 recommends an inlet air temperature of 20 to 25°C, which is endorsed and backed by the server vendors and their warranties. Temperature fluctuations should be no more than 5°C over 60 minutes. Fluctuations and constant exposure to temperatures outside of this band will degrade the useful life of the IT equipment. In fact, research conducted by The Uptime Institute has shown failure rates exceed normal field experience by more than four times.

The series of temperature points at which actions are taken vary from one server manufacturer to the other. However, the default first level warning to the user is typically issued at 55°C. The second and critical threshold is at 65°C. The server will again notify the user through the operating system. If no action is taken and the temperature remains above 65°C for 20 seconds or more, an automatic shut down command of the operating system and power supply is issued likely resulting in loss of data to the users.



A typical server will automatically shut down at 60 to 65°C as a self-protective measure. The temperature is measured on or near the chip thus it does not directly correspond to cabinet inlet air.

Real Data Center Meltdowns

Several real-life studies have been conducted on thermal shut down in data centers during cooling outages. Several factors come into play when the data center or parts thereof will shut down due to loss of cooling:

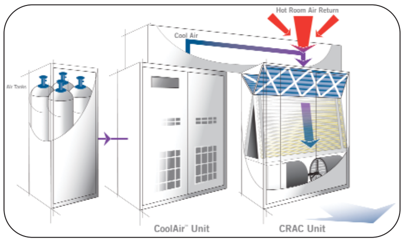
- Volumetric size of the room. The taller the ceiling, the more heat will rise and accumulate under the ceiling or ceiling tiles rather than in the aisles.
- Server workload. If the server workload and thereby the heat output is low, it will extend the time marginally.
- CRAC (computer room air conditioning units) fans on UPS power. Time will be extended if the fans in the CRAC units continue to run even though the coil provides no heat removal.

Data points collected through research conducted by The Uptime Institute, Emerson Corp., EYP Mission Critical Facilities and Active Power, Inc., has shown that although the industry average 1500W/cabinet heat load can run for 40 to 50 minutes without cooling, the 30kW/cabinet heat loads gives the user less than 15 seconds to react.

UPS Providing Power and Cooling

Active Power's CoolAir is an innovative energy storage system that provides both power and cooling during a power outage. The figure below shows a block diagram of the TACAS technology. The complete functioning of this technology can be categorized into three sections:

- When utility power is available
- When utility power is lost
- When utility power is restored



The flywheel provides instantaneous power until the turbine/alternator is available. The thermally-charged air drives the turbine/alternator, providing power for extended periods of time. Frigid air is discharged as a by-product of the process.

When utility power is available, a flywheel constantly spins by drawing power off the UPS, which is similar to the trickle charging of batteries. As it spins, it stores a certain amount of rotational energy. Compressed air is stored in standard air tanks placed within modular cabinets. All the tanks are connected in parallel and the pressure is equalized among all the tanks.

The thermal storage unit (TSU) provides a means to control the system discharge air temperature and to optimize the air flow requirements for maximum utilization of stored air. The unit is a simple block of metal with air passages and is kept hot using modular, cartridge-type heating elements. The power required to maintain the TSU temperature is also obtained through the DC Bus of the UPS. High-grade insulation is used around the TSU to minimize the heat losses.

When utility power is lost, the flywheel starts acting as a generator and its rotational kinetic energy is converted into electrical energy to provide power to the load instantaneously in the event of a power outage. Once the flywheel speed drops below preset levels, compressed air starts flowing through the TSU picking up the stored thermal energy. The energized hot air is then used to drive a high-speed expansion turbine that is connected on the same shaft to a permanent magnet alternator. The output of the alternator is a high frequency alternating current (AC), which is converted to a direct current (DC) to be supplied to the DC Bus of the UPS. A unique feature of this technology is that during discharge, the expansion of compressed air provides a discharge of cool air.

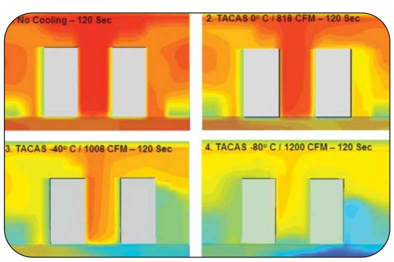
"The technology for the flywheel is decidedly simple and low tech. The design philosophy results in high reliability and low cost." Electric Power Research Institute, Inc., November 2005

Modeling the Results

To demonstrate the cooling capabilities and application of CoolAir, several computational fluid dynamics (CFD) models have been created with the following values:

- Room envelope: 30 by 28 by 10 feet floor to ceiling
- Under floor cold air distribution: 18 inch raised floor
- Hot aisle (4 feet)/cold aisle (4 feet) layout
- Single 25 percent open perforated tile at each rack front
- Uniform load across 14 (70 kW) rack spaces
- Down flow CRAC: 20 tons
- Total airflow from CRAC: 11,000 CFM
- Theoretic room air displacement cycle: 79x/hour
- UPS/TACAS energy storage solution: 100 kVA/80 kW

The discharge side of CoolAir is coupled to the overhead return inlet of the CRAC unit using a simple mixing chamber with no fans. The mixing chamber will allow for an even distribution of the cold air over the inlet to the CRAC unit and to ensure appropriate mixing. The fans in the CRAC unit are fed with power from the UPS (approximately 3 kW in this case) during a power outage while the coils, chillers or condensers are off. The fans ensure hot air from the hot aisle continue to be returned to the CRAC unit. The relatively low volume, but very cold discharge air from the system mix with the hotter air resulting in colder air returned to the raised floor.



The discharge air from the CoolAir, only available during a power outage, can provide air at various temperatures and volumes.

Figure 4 shows CFD modeling at 5 kW/rack 120 seconds after loss of cooling in four individual scenarios.

1. No emergency cooling
2. TACAS as emergency cooling 818 CFM at 0°C
3. TACAS as emergency cooling 1,008 CFM at -40°C
4. TACAS as emergency cooling 1,200 CFM at -80°C

5,000W/Rack	Self-Protective Shutdown	Improvement
No Emergency Cooling	189 Seconds ~3 Minutes	0% [baseline]
TACAS 0° C	247 Seconds ~4 Minutes	30.7 %
TACAS -40°C	646 Seconds ~11 Minutes	242%
TACAS -80° C	Indefinite	

The figure shows CoolAir can provide enough emergency cooling to keep a data center running indefinitely at -80°C.

According to the data points in figure 1, the server equipment in the room would perform a self-protective shut down after 189 seconds (approximately three minutes) without an emergency cooling solution like the TACAS technology. Data points in figures 2, 3 and 4 using TACAS technology as emergency cooling during a power outage show a significant improvement, keeping the data center running indefinite at -80°C discharge.

Compressed Air to Provide Both Power and Cooling

CoolAir has proved to be a simple and excellent replacement for lead-acid batteries in UPS systems. Unlike toxic, lead-acid batteries, there are no hazardous by-products or disposal issues with TACAS. While batteries require regular maintenance and must be replaced every three to five years, CoolAir features low maintenance and is completely renewable over a 20-year lifespan. Combined with the ability to provide energy storage and runtime that is far more reliable and predictable than that of legacy battery based systems, total cost of ownership is reduced and far easier to predict.

The capability of being able to cool a data center during a power outage using cold air discharge is both unique and never before seen in the industry. The versatility and flexibility of CoolAir is such that it can be coupled to most UPS systems using a standard IGBT (insulated gate bipolar transistor) based converter. It is important to note the solution is not limited to 100 kVA data centers and below. CoolAir can easily be deployed in enterprise data centers where pods or zones of high-density cabinets that would be of particular concern during a power outage exist. In addition, there are significant cost and energy efficiency savings to be made by deploying CoolAir to bridge power and cooling simultaneously during the 60 to 120 seconds it would take for the full building cooling system to come back online after a power outage.

Martin Olsen serves as director of Product Management and Development for Active Power, inventor and manufacturer of the most reliable and energy-efficient critical power systems in the world. If you'd like to access the power and cooling study highlighted in this article, please visit www.activepower.com/gonein60seconds.