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design PLUS

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Professional Engineering Services
For Mission Critical Industries

designPLUS

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During the past few months, ***FEA*** has been asked to provide several presentations on the concept of "N" redundancy. It has become obvious that this is an area that needs more attention in the designPLUS Newsletter. Our first thought was to reprint a previous article regarding "N" redundancy, but much to our surprise we had never published such an article. This concept is so basic to mission critical design, we never addressed it in great detail. We have articles on 7x24xForever, dual power cord, "Nines" availability, and "N" redundancy as it relates to specific systems, but never an article just explaining the concept of "N" redundancy. You will find an article in this newsletter outlining the "N" concept. We hope it helps explain the different types of redundancy that can be applied to various systems.

Buying Mission Critical Design Services

by Leo P. Soucy, Jr., P.E.

FEA has been asked to provide design services for mission critical facilities in a number of different arrangements including competitively bid to the Owner, competitively bid to an architect and negotiated directly with the Owner. If a competitive bid is preferred, it is important that all the firms asked to provide a proposal are aware of the specialized services required to deliver a mission critical facility. As with any specialized facility, previous experience is the best indicator of a project's success. ***FEA*** would not consider designing a museum, for example, as we have no experience in this area.

Although the design of mission critical facilities involves applying standard engineering principles, the emphasis must be on reliability, redundancy, fault tolerance and 7x24xForever operability. Meeting these design criteria requires special attention as to how each system is configured and how it will interact with all other critical systems, not only in 'normal' operation, but also during an emergency or an equipment failure. ***FEA***, as well as most other mission critical design firms, provides extensive after-design services that are not normally provided by design firms engaged in the design of non-mission critical facilities. These added services include extensive construction administration follow-up, submittal review at the manufacturer's site, factory witness testing of all major equipment, detailed start-ups, commissioning and integration testing. These added testing services provide mission critical design firms with extensive equipment experience and in-depth knowledge in the operation and integration of the major critical systems. ***FEA*** calls this premier service "designPLUS", and an outline of these services can be found on our web site www.feace.com.

FEA has found that not only data centers require mission critical facilities but many other industries including broadcast, healthcare and pharmaceutical. We have been involved in the forensic analysis of failures in many highly critical operations that have been designed by firms commissioned to design a complete facility without having any mission critical design experience. The analysis of the failure showed that the highly critical operation did not receive the attention it required, as the design firm did not understand the design concepts necessary for this type of facility.

Having performed "Reliability Reviews" of systems that were not properly designed, we have found that it can be extremely expensive to upgrade to the intended functionality, and at times impossible, especially if the mission critical facility is already on-line.

Common Cause Failures

by John M. Lane, P.E.

A common cause failure is a single event which causes failures on more than one system. Care must be taken to limit the probability that a single event can simultaneously affect redundant critical systems. At ***FEA*** we call this the "Fault Tolerant" design criteria where a system continues to function even after a single fault occurs.

We can divide common cause failures into two categories; inherent to the facility and operation related. Some areas where there is a high probability of inherent common cause failure are where redundant critical equipment; generators, UPS systems, chillers, etc., are located in the same room. Fire, flooding, sabotage, water or fuel leaks, etc., in one of these areas can simultaneously damage both systems resulting in a long-term facility outage. Providing physical separation will reduce the probability of this type of common cause failure. Routing of critical redundant services such as utility and generator power, chilled water loops, or dual cord rack power without ample physical separation should also be avoided for the same reasons.

Critical equipment that is reliant on a single subsystem is also susceptible to inherent common cause failures. Many generators relying on a single fuel pumping system, outside air louvers that do not fail open, a common exhaust stack, or contaminated fuel are just some examples of common cause failures that can result in the failure of the entire generator plant. A chilled water plant that relies on a common header or non-maintainable chilled water loop is susceptible to inherent common cause failures. A chiller plant that is controlled by a non-redundant building automation system to automatically restart chillers or chilled water pumps will not operate properly if the control system fails.

Critical systems should be fed from different, totally separate, redundant power systems. Powering "A" and "B" dual power cord equipment from different power distribution units or critical air conditioning units from different panelboards will not be effective if they are served by the same source of power.

Operational common cause failures are normally caused by human error and are normally harder to avoid. An example would be a vendor making the same error servicing all the facility's STSs or installing faulty control boards in every UPS module. Servicing one system per trip can reduce the risk of this type of operational common cause failure. Installing proper signage and alarmed covers over EPO stations will reduce the probability of inadvertent EPO system activation. The probability of operator error can be reduced with proper training of personnel and detailed operating procedures but can not be totally eliminated.

These are some examples of the items which must be integrated into the design of a mission critical, 7x24xForever, N+N facility.

Redundancy Review

By Brian Soucy

Protecting a mission critical facility requires matching the infrastructure investment with the required level of protection. Undoubtedly, this requirement will lead to a discussion of redundancy. Redundancy is often discussed in terms of modules or systems, commonly referred to as 'Ns'. 'N' represents the minimum number of modules or systems required to meet the load.

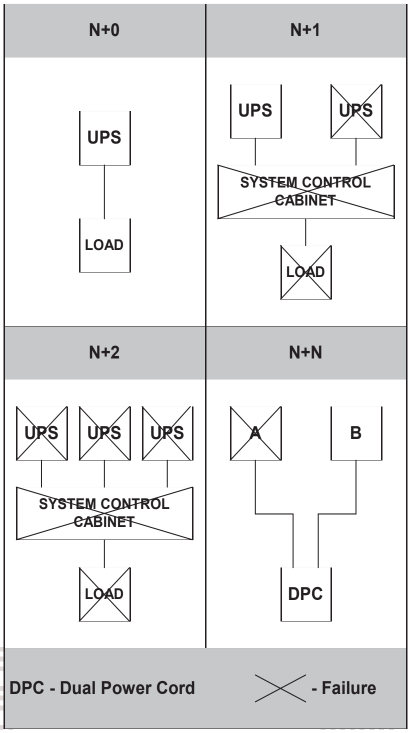
The simplest configuration would be N+0. N+0 systems provide zero redundancy and a failure of one unit will adversely affect the critical load. In practical terms, this configuration may include one utility, one generator, one transfer switch, one chiller or one UPS. For example, a 1500 kVA UPS system consisting of three, 500 kVA UPS modules serving 1500 kVA of load is an N+0 system. While the components provide a level of protection during a power outage, the critical load would be adversely affected if the outage occurred while a generator or UPS were offline due to maintenance or failure.

N+1 provides a single system with one additional module above that which is required to serve the load. The loss of one unit being offline for maintenance or failure will not adversely affect the critical load. An N+1, N+2 or N+X system implies a system consisting of multiple modules (building blocks) but with a common point of connection such as a UPS output bus (or system control cabinet) or a common header/loop for a chilled water plant, with multiple chillers. However, while N+1 means redundant units or subsystems, it is still a single system. If a common key component fails or is shut down for maintenance, it would adversely affect the critical load.

N+2 provides a single system with two additional units over that required to serve the critical load. The loss of two units being offline for maintenance or failure will not adversely affect the critical load. This system configuration is provided if the owner requires that the system always remain at least N+1 redundancy even if one unit is offline for maintenance or failure. This system configuration still has a single control unit.

N+N or 2N provides two completely separate systems each sized to serve the entire load. 2N systems are completely isolated from each other and have no common point of coupling. Sometimes there are means, such as a tie circuit, provided for manual switchovers as a backup but the two systems are isolated under normal conditions. If one of the systems fails or is shutdown for maintenance or upgrade, the critical load is served by the other system and is not adversely affected. This is the system configuration that is now being implemented to support mission critical data centers utilizing dual power cord computer equipment.

When evaluating a system's redundancy it is important to consider all components. While the generator and UPS capacities may be sized for N+1 operation, other limiting factors should be reviewed. For example, a facility with an N+1 generator installation or UPS system will only be as reliable as the common system control cabinet in the event of a power outage. A 2N design would eliminate this constraint. Figure 1 shows failure modes of the different types of system redundancies.



Upgrading from an N+0 system to an N+1 or 2N system can be a costly proposition. Ultimately, a system's redundancy and the corresponding investment should reflect the criticality of the load, its tolerance of a power outage and the acceptable level of risk an organization is willing to assume. Considering these factors may not only help justify, but make the added infrastructure investment a requirement.

Food for Thought

We are presently working on a broadcast project in NYC with Bice C. Wilson, AIA, of Meridian Design. He had a very interesting perspective on mission critical broadcast facilities with regard to electrical power. He said,

"The product that media and telecommunications companies sell is re-modulated electrical power - hence, their raw materials are electricity and the creative people and tools by which that energy is re-modulated."

This quote can also be used for any data processing operation and shows how inter-related the successful operation of a mission critical facility is with highly reliable power.

Policy

designPLUS Newsletter is published to keep the readers current with the latest trends in mission critical systems.

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Computational Fluid Dynamics – CFD

by Francis W. Escott, P.E.

It is a well-documented fact that as the computational power of servers increases, the heat load associated with these servers also increases dramatically. Air conditioning systems that were the norm for Data Centers can now no longer handle the increased load. As new Data Centers come on-line or existing Data Centers are upgraded, different methods of providing the required air conditioning are now mandatory.

The problem isn't that sufficient air conditioning cannot be provided but that air conditioning must be provided where it is required. This means that the cold air stream that provides the cooling must be analyzed from the generation of the cooling air in the CRAC along the path through the Data Center to the return to the CRAC

Each Data Center presents a unique cooling problem to resolve. By following a series of logical steps, a resolution can be generated for each specific situation.

The first step is to clearly and adequately define the problem. This is not as simple as defining Hot and Cold aisles, under-floor or ducted air distribution, or how many CRAC units are required to satisfy the BTUH requirement. What is required (as a minimum) in general terms are the following items:

- Location of the walls, floor deck and raised ceiling
- Location of all the racks (number of rows and racks per row)
- Heat load of the individual racks (especially the high density heat loads)
- Configuration of the rack rows (parallel or perpendicular to the CRAC units)
- Number and location of the CRAC units
- Number and location of the perforated tiles of overhead diffusers
- Any other item that would affect the cooling air stream

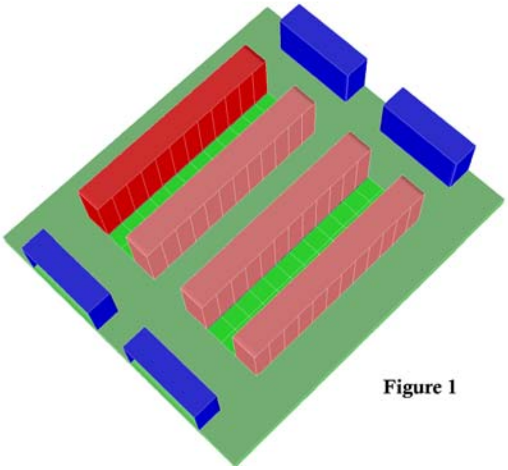

Figure 1

The second step is to analyze the entire Data Center as a system. The application of fluid mechanics in the form of a Computational Fluid Dynamics (CFD) system analysis is one of the most applicable tools that can be applied to the Data Center cooling system as a whole. CFD is capable of calculating and showing graphically the airflow, air velocity, pressure distribution and the complete air path of the entire area under consideration. The results of a complete CFD evaluation of a Data Center show the following items of information:

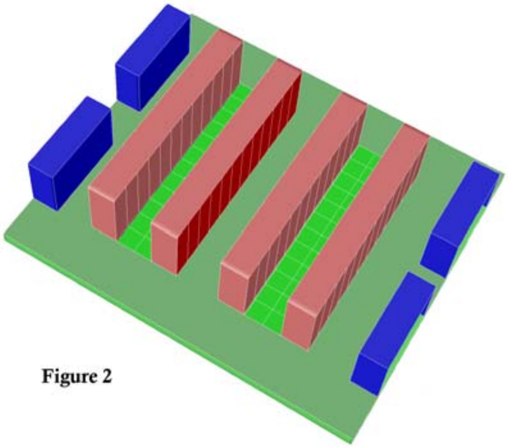

Figure 2

- Airflow from the CRAC units
- Air data under the raised floor (airflow, air velocity, pressure distribution)
- Airflow through the perforated tiles into the cold aisles
- Airflow through the cold aisles
- Airflow through the server racks
- Airflow into and out of the hot aisles
- Airflow around any obstacles in the air stream

The same graphical representation for air velocity and air temperature as airflow can be displayed thereby showing the complete picture of the Data Center cooling system

FEA, in conjunction with Fluent Incorporated, has created the following analysis of a representative Data Center. The results graphically point out where the problems lie and in knowing this, solutions can be designed into the project without waiting for them to cause problems in the field.

Figures 1 and 2 represent the sample Data Center with the rack rows either parallel to or perpendicular to the CRAC units.

Figures 3 and 4 show the airflow from the CRAC units under the floor and up through the perforated tiles. This graphically indicates that the orientation of the rows is not a major factor in the air stream.

Figures 5 and 6 show the continuation of the air stream through the racks back to the CRAC unit.

These Figures indicate that everything looks like it will work; however, these figures are the end result of several problem solving computer runs.

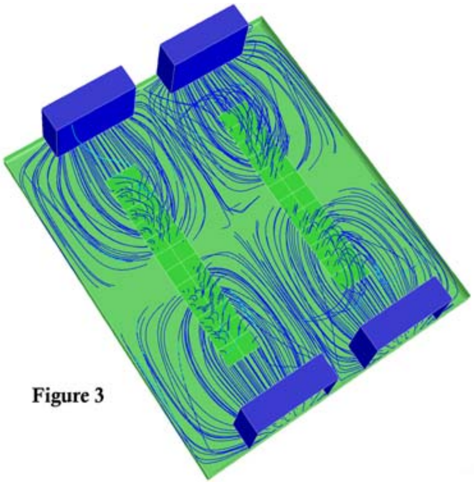

Figure 3

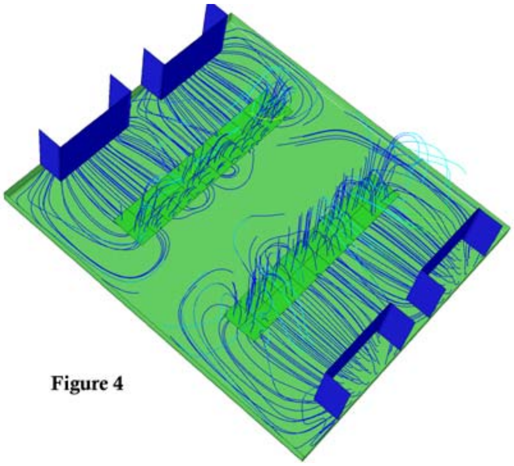

Figure 4

The major problem of not providing sufficient cooling air to the racks is dramatically shown in Figures 7and 8. Figure 3 shows the result of having high-density (darker red color) racks on the opposite side of the cool aisle from lower density racks. The top part of the lower density racks do not get sufficient cool air because the high density racks steal the air causing the warm air from the discharge side of the racks to wrap around the top of the rack and enter the topmost rack of the lower density side. Figure 8 shows the result of not supplying sufficient cool air to the cool aisle when racks of equal density are located on either side. This time the warm air not only wraps around the top but also wraps around the end of the racks.

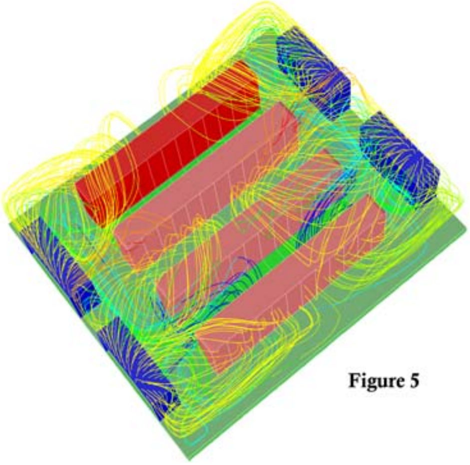

Figure 5

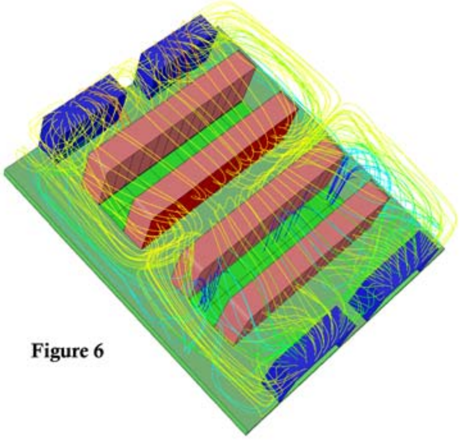

Figure 6

FEA and Fluent Incorporated consider CFD to represent one of the most powerful analytical tools that can be used in resolving problem areas within existing and new Data Centers.

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Kishor Khankari, Ph.D., of
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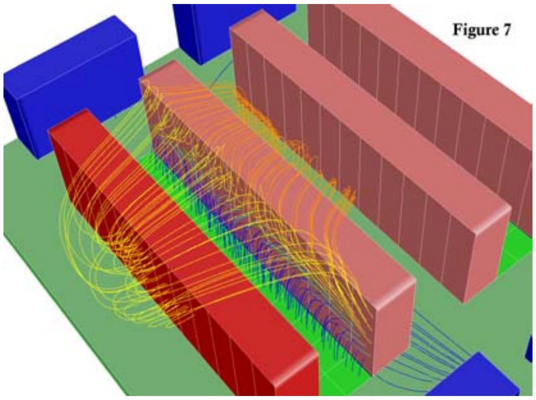

Figure 7

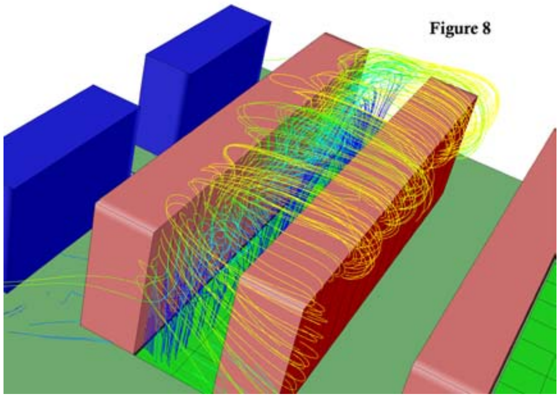

Figure 8