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SPRING 09

A Green Approach to Building a Superior Data Center

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Modularity in the data center power infrastructure

2009 7x24 Exchange **Spring** Conference • End to End Reliability: "**Managing Data Centers in Turbulent Times**"
Boca Raton Resort and Club in Boca Raton, Florida • May 31 – June 3, 2009

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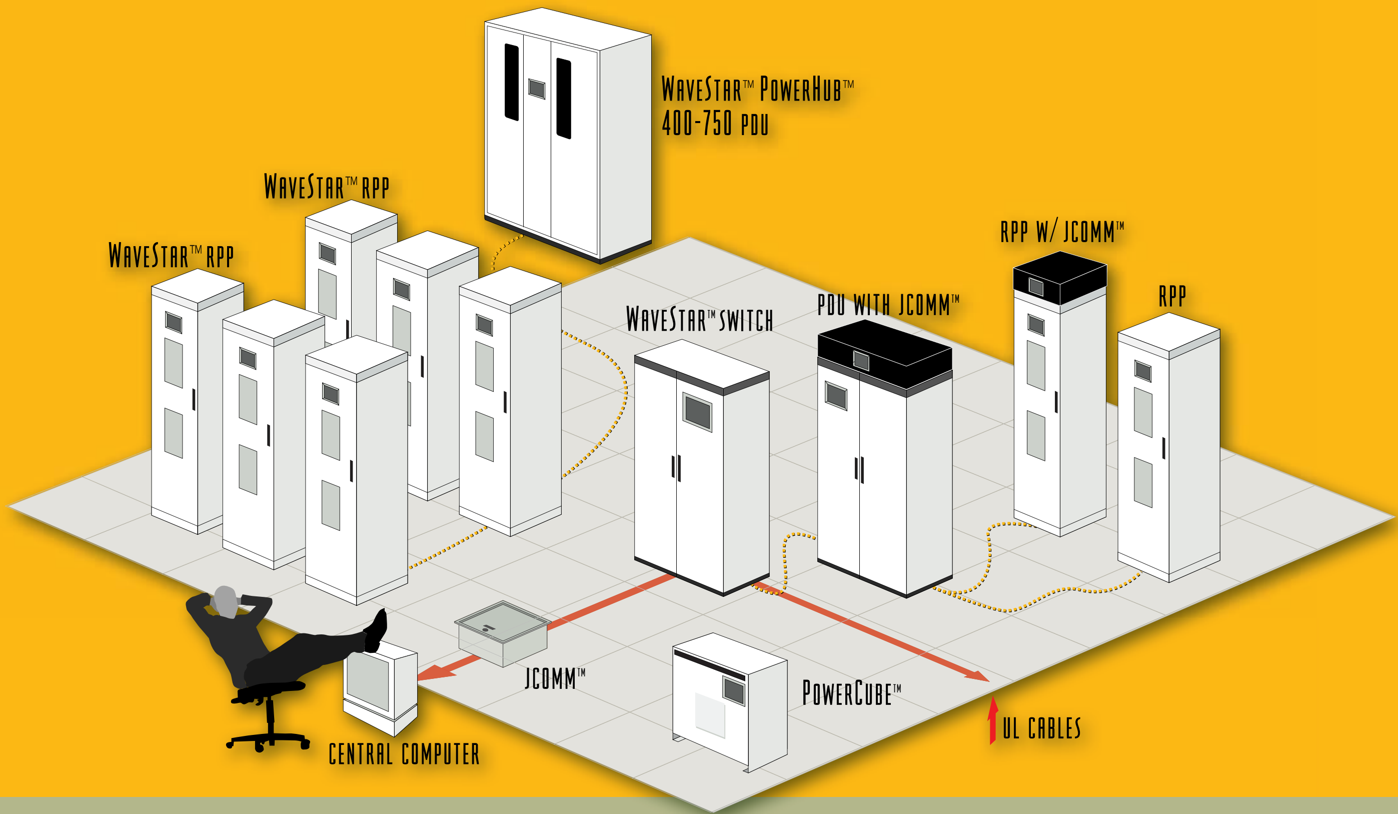

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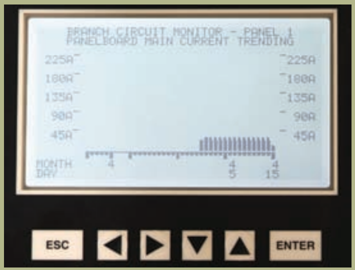

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Robert J. Cassiliano

CHAIRMAN'S LETTER

I hope everyone is excited as Spring begins!

The current economic environment has created an extremely challenging landscape for mission critical professionals with clients scaling back or canceling projects, service providers and customers reducing resources, and companies seeking to pay less for goods and services. With this as a backdrop companies still require their data centers to be extremely reliable, provide high availability, run cost effectively and be energy efficient. Operating within these parameters presents a unique opportunity for companies to provide creative solutions for their clients. Firms that are innovative will achieve business success and those that are not will surely struggle.

In light of this the theme for the 2009 7x24 Exchange Spring Conference being held at the Boca Raton Resort and Club in Boca Raton, Florida May 31 – June 3, 2009 is End to End Reliability: "Managing Data Centers in Turbulent Times." Conference highlights are as follows:

- Conference Keynote: "Plain Talk: The Economy in the Age of Obama" presented by Stuart Varney, Business and Financial Journalist for FOX News
- A panel of Industry Experts including Microsoft, SUN, Vanguard, Digital Realty Trust and Comcast to discuss Managing Data Centers in Turbulent Times, moderated by Kevin Heslin Editor of Mission Critical Magazine
- An EPA Update
- Exchange Tables on specific topics at all breakfasts and Monday lunch
- An End-User Interactive Exchange Luncheon on Tuesday
- Vendor Knowledge Exchange on Tuesday afternoon

The program content is designed to provide value to conference participants and their companies by focusing on important topics of the day. The Board of Directors encourages your comments on the 7x24 Exchange Conference Program.

I look forward to seeing you at our Spring Conference in Boca Raton, Florida!

BUILD FOR TODAY. EXPAND ON DEMAND.

MODULARITY IN THE DATA CENTER POWER INFRASTRUCTURE

Anderson Hungria

The data center—one of many at the telecom service provider—represented a Utopian vision. The top-of-the-line facility had expansive floor space, twin power utility feeds, and the latest power and cooling systems. Sitting in the middle of the vast data center, like lonely chess pieces, were six racks – about four percent of the data center's potential utilization.

"Build it and they will come," had been the philosophy for establishing the luxuriously over-sized data center, as well as the company's other data centers.

But the people didn't come. Ultimately, the service provider joined the annals of good intentions that failed, and their data centers were sold for pennies on the dollar.

Even if the people had come, this data center strategy would have been unnecessarily costly. If you overbuild today just to be ready for an uncertain future, you will foot the bills now for space and support infrastructure that may or may not ever be needed. Even if you could justify the cost, the power infrastructure would operate far below capacity and be very inefficient as a result. "With the cost of mechanical and electrical equipment, as well as the price of power, this model no longer works," wrote David Cappuccio in IT Modernization: Build Agile Data Centers While Reducing Expenses (Gartner RAS Core Research Note G00156314 – April 18, 2008).

However, overbuilding is still the norm today – partly because design principles from the old mainframe days still prevail, and partly because data center managers fear running out of capacity.

That's not an idle concern; 41.7 percent of data centers will run out of power capacity in 2009-10, according to Uptime Institute (Data Center Capacity and Energy Efficiency, March 2008). That's a scary proposition, especially as new server architectures exponentially increase the demand for power, outlets and redundancy.

So what is the best approach? You don't want to pay for excess capacity now, but you don't want to get caught short in the future.

"Building a whole data center to the highest energy point is expensive and a needless over-engineering exercise," wrote Rakesh Kumar and Philip Dawson in "The Data Center as Living Organism: Why History is not a Good Guide to the Future" (Gartner RAS Core Research Note 153516, December 7, 2007). "The design principle in Generations 1 and 2 [mainframe and client/server environments] was around a single static structure. New designs need to be modular, with built-in expansion capabilities."

Kumar and Dawson advocate modularity in the physical space, building out the data center in sections, perhaps 10,000 square feet at a time. Initial capital outlay is lower, and future builds can capitalize on emerging technologies. Cappuccio also recommends clustering IT systems with high power demands in "high-density" zones, so the power infrastructure can be closely tailored to the needs of a rack or row. There's no need to provide highest power capacity to every square foot of the data center, if only a certain percentage of the racks will need it.

Tailoring the power infrastructure in this manner can be readily achieved with today's modular components. But the benefits of modularity are also seen in creating a power system that is as adaptable as the data center needs to be.

Virtually every large data center undergoes moves, additions and changes (MACs) once a month or more, according to a Network Computing survey of 474 IT managers (Frequency of MACs, Eaton-sponsored study, July 2006). Frequent change affects 85 percent of mid-sized data centers and 67 percent of small data centers, according to the report. Modular power systems can adapt to such dynamic environments. Build what you need, redeploy later, and expand as needed.

MODULARITY IN THE DATA CENTER POWER INFRASTRUCTURE

Modularity means many things to IT managers, such as: incremental data center build-outs in pods, universal racks, blade servers, stackable storage arrays and so on. In the power world, modularity can mean UPSs that scale for added capacity or redundancy, extended battery modules to customize backup runtime, and plug-and-play power distribution components that break down room-level wiring into row- or rack-level modules.

For all these interpretations of modularity, the underlying concept is the same: provide a function or process in building-block fashion, and enable users to add, remove or redeploy those building blocks to create variations of the original function or process. Modularity enables you to:

- Pay only for the functionality you need in the short-term.
- Plug in new capacity or functionality when the time is right.
- Expand at your own pace, without starting over with a new platform every time you want to grow or upgrade.

Let's take a look at how those concepts and benefits apply in power quality systems, battery backup, and rack-level power distribution.

MODULARITY IN POWER QUALITY SYSTEMS

Historically, many data centers chose a centralized power protection strategy, where a large, standalone UPS powered the entire data center. This approach works when growth can be accurately forecast, but as we've seen, the data center is a rapidly changing scene.

In recent years, many data centers have adopted a zoned strategy, where the data center is divided into zones, each powered by its own UPS. This approach is more scalable than a centralized UPS strategy, and a UPS failure would only affect a single zone, not the whole data center.

The zone concept advances into the age of modularity with a distributed UPS strategy, where each rack or set of racks has its own UPS—and the UPS itself is modular to expand as needed. Redundancy can be established through paralleling, to establish Tier II and higher reliability.

In paralleling, two or more UPSs are electrically and mechanically connected to form a unified system with one output—either for extra capacity or redundancy. In an N+1 redundant configuration, you would have at least one more UPS module than needed to support the load. As a conjoined system, each UPS stands ready to take over the load from another UPS whenever necessary, without disrupting protected loads. Paralleling provides an excellent solution for matching growth while extending the value of existing UPSs. Going modular does not have to compromise reliability.

WHAT TO LOOK FOR IN A MODULAR UPS

- Small footprint, high power density per rack
- Ease of installation, without the need for an electrician
- Ability to install the UPS in your existing racks, if desired
- Ability for the UPS to share a rack with IT and power distribution equipment
- Expansion options in building-block increments
- Hot-swappable components for ease of replacement and upgrade
- Ready for "plug-and-power" distribution
- Paralleling for synchronous function as a single unit
- Option to expand battery runtime as needed
- Provisions to ensure reliability of parallel operations
  - Peer-to-peer control rather than "master-slave"
  - Synchronization to a bypass source rather than a master controller
  - Load sharing does not depend on inter-module wiring
  - Selective tripping to instantly isolate a unit with a fault

MODULARITY IN BATTERY BACKUP

A typical data center might only resort to battery power for a few minutes a year, or perhaps a few minutes over the entire lifetime of a UPS. But for most data centers, battery backup is still a lifeline for business continuity, and battery demand continues to escalate. That means battery backup systems must be as modular as the UPSs they support.

All UPSs must have batteries that support the load for a few minutes during a power outage—long enough to gracefully shut down systems or start up a generator. Large centralized "monolithic" UPS usually need multiple dedicated battery cabinets to achieve even a minimum acceptable runtime. In a modular UPS, internal batteries to each power module provide sufficient system runtime without adding any additional footprint or complexity. However, if you need more runtime than that, look for a UPS that also supports external battery modules.

THE CHALLENGE OF BATTERY MANAGEMENT IN MODULAR CONFIGURATIONS

In traditional parallel configurations, battery management has been a challenge. The entire system has been somewhat at the mercy of the weakest battery in the setup. Here's why…

Parallel UPS configurations are programmed to share the load evenly among all active UPS modules in the group. Trouble is, although the UPS electronics modules are equally capable of handling equally shared loads, their batteries might not be. Batteries age and deteriorate at different rates. A parallel configuration could easily have a mix of strong batteries and weak ones.

If the parallel configuration must resort to battery power during a power outage, some batteries will be up to sharing the task equally, others might not. That reality can trigger a troubling chain of events. The weakest battery is depleted early on, causing its associated UPS module to go into under-voltage alarm and shut down in self-protection. If the remaining units in the parallel configuration cannot support the total load, the whole system will fail, even before completely draining all the available batteries.

This problem actually still exists with most parallel systems on the market today. In a well-known competitor's system, a fault in a single battery string may affect the performance of the overall system and create a single point of failure, potentially causing a system failure.

Eaton considered this domino effect to be an unacceptable risk for modern data centers. The BladeUPS system alleviates this problem by intelligently monitoring the health of each individual battery module and—during outage conditions—properly adjusting load distribution to take advantage of the strongest batteries, rather than being constrained by the weakest. This innovative feature ensures maximum runtime out of the connected batteries, while protecting UPS inverters from exceeding their rated capacity.

MODULARITY IN POWER DISTRIBUTION

With data center devices smaller than ever—often served by dual or triple power supplies—a single rack of equipment might produce 40 or more power cords to manage. Power consumption per rack is higher than ever, and continuous uptime is essential. What's the best way to distribute power to racks in the era of modularity?

The conventional approach has been to bring power in from the centralized power system (UPS) to a transformer that "steps down" power to the desired voltage. Power then goes through the main breaker to a panel board, then to power strips in racks. The complexity of this arrangement – particularly multiple connections from panel board to power strips – makes it expensive, difficult to install, hard to monitor and not particularly resilient to change.

A far better alternative is to use a rack power module to provide "plug and power" distribution from a UPS or panelboard to an enclosure-based power distribution unit (Eaton refers to them as ePDUs) or directly to IT equipment. Select a rack power module that can deliver power in an organized manner to loads of various voltages, input power cord types and output receptacles—supporting a broad range of applications.

In order to truly support modularity, this rack power module should be adaptable to serve either of two roles:

- Primary power distribution from the UPS to a PDU—Select a rack power module that can be hardwired, delivers high power (36 kW), provides metering and monitoring, and has 12 poles of distribution breakers—essentially bringing the characteristics of a panelboard into a portable 3U box.
- Secondary power distribution from a PDU or panelboard to IT equipment—Where you formerly had many long cable runs (home runs) from a panelboard to enclosures, the rack power module simplifies the cabling and makes it easier to track the power path when adding or changing IT equipment.

For either application, the modular approach has fewer cables to manage and greater flexibility, both for changing the IT equipment and the distribution system that powers it.

WHAT TO LOOK FOR IN MODULAR POWER DISTRIBUTION

- Compact size, such as 3U for a rack power module, 1U or 2U for an enclosure-based PDU
- Ability to mount the device anywhere, not just in one vendor's rack or a specified slot
- Installation options that conserve valuable U space and support easy cable management
- Ability to easily move, redeploy and swap out ePDUs without tools or an electrician
- Ability to install ePDUs horizontally or vertically, multiple units per rack
- Display of load currents for load balancing and protection during moves, adds and changes
- Ability to monitor ePDUs over the network through IP communication
- Sufficient power capacity and receptacles to meet projected needs for 12-18 months
- Additional functionality, such as remote control or receptacle-level metering, if possible

THE CHALLENGE OF MONITORING MODULAR POWER DISTRIBUTION

Data center managers could rightfully wonder if modular power distribution might be more difficult to monitor. After all, there will be dozens or even hundreds of ePDUs to track, compared to a few power distribution racks. That concern is fair enough. In the past, managing all those rack-level power distribution devices has been problematic, for a couple of reasons:

- With older or very basic ePDUs, there is typically no visibility into current flow at this level. If an overload condition or tripped circuit is imminent, customers wouldn't see it coming.
- With newer ePDUs networked over the company LAN, users typically have to point their Web browsers to each device to see its status – a time-consuming and tedious proposition.

Those compromises are no longer necessary. With the latest ePDUs and software, you can monitor and manage network-connected power distribution components at the rack level via one Web-based user interface and one IP address. Straightforward and budget-friendly software is available to aggregate power data from a virtually unlimited number of ePDUs and UPSs on an IP network into a cohesive, enterprise-wide view. Going modular doesn't have to compromise visibility; in fact, it extends visibility further to the edge of the distribution system.

HOW DOES MODULARITY AFFECT RELIABILITY?

Traditional thinking held that when you adopt modular components, you increase component count, and with more components comes more risk of component failure. Modularizing a system—for instance, using a bank of 12kW UPS modules instead of a larger, stand-alone UPS system—would certainly increase the number of internal electronic components and connectors. Could more parts translate into more potential points of failure?

Not so, with other advantages inherent in modern UPS designs:

- Redundant modules operating in parallel can cover for an individual module that is removed from service, without affecting overall system performance.
- Whereas older, monolithic UPSs were difficult to move and replace, small "hot-swappable" modules can be removed and replaced by one or two technicians, often without assistance from the vendor.
- Modular component tend to be manufactured in much greater quantities than non-modular systems, so they benefit from the quality improvements of more mass production, less manual intervention, during manufacture.
- Replacement components, such as electronics module and battery are more easily available and cheaper to maintain.

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Power Generation

By extension of its mission, the BJC Healthcare system cares for the ecosystem that surrounds its communities, which translates into incorporating sustainable measures and diversity in every business and social opportunity that presents itself.

When BJC decided to construct its new 40,000-square-foot primary service, Tier III data center in O'Fallon, Mo., which is adjacent to one of its member hospitals, it partnered with Clayco, a full-service real estate development, design and construction firm with a proven track record for innovative green practices. The project, which will begin in late February 2009 and be completed in the first quarter of 2010, is seeking Leadership in Energy and Environmental Design (LEED) Gold certification with the United States Green Building Council (USGBC), a lofty but rewarding goal.

A GREEN

TO BUILDING A

Mission critical data centers are typically very complex facilities which require vast amounts of energy – often 50 times more than that used by a conventional office building. These facilities also create tremendous amounts of heat but must be operated under strict temperature and humidification conditions. Thus, adapting sustainable practices in the building of a high-energy consumption data center infrastructure presents a series of unique challenges.

GOING FOR THE GOLD

In an effort to curb this energy consumption, BJC and Clayco placed a great deal of emphasis on designing and utilizing innovative and highly-efficient mechanical and electrical systems.

In place of typical heating and cooling systems, the BJC Data Center is installing an economical, high efficiency and eco-friendly water-cooled central plant. In the spring and fall, and when the ambient temperature outside are at an acceptable thermal condition, this system will greatly reduce the use of the chiller capacity, significantly reducing energy use. This high efficiency system will also utilize refrigerants and equipment specifically designed to reduce ozone-depletion potential and global warming impact.

Within the data center concentrated rack areas, the project team has introduced a high density heat containment system, which will take the heat generated from out of heavy, hot server racks on the data center floor and channel it out of that space so that the equipment area is constantly cooled. By introducing this heat back through the central mechanical system, the center will preheat the domestic hot water systems for the neighboring medical office building. This recycled heat is used to heat the central water systems for showers, equipment processing and cleaning.

While water is a natural enemy in data centers, due to its lethal potential to the critical equipment in the building, the project team was able to somewhat ironically reduce, contain and filter generated storm water run off from the site and incorporate high efficiency, low flow plumbing fixtures within the building, greatly reducing the reliance on municipal domestic water uses.

In consideration of the local ecosystem, the team has also incorporated bioswale wetland filter systems throughout the project site to capture excess run-off and improve stormwater quality levels before reentering the local stream systems.

building exterior. Salvaged material elements will also be incorporated and include the reuse of crushed concrete materials from the old foundations of demolished buildings to be re-used as the underlayment of the parking surfaces and potential use of salvaged raised access flooring systems and materials.

By going the extra mile to achieve the LEED Gold certification, we are designing and building a data center with over 18% better energy efficient standards than a traditional data center. As data center facility managers see the return on investment and environmental impact of sustainable building, further advances are expected in this evolving industry. ■

APPROACH

SUPERIOR DATA CENTER

Jaime E. Kelley
Paul T. Merrill

RECYCLING RESOURCES

During early planning stages, the project team established a commitment to an approach with a holistic point of view, taking into consideration every material and resource that was going to be extracted, manufactured or produced for the project. The design-build team will be taking extraordinary measures during the physical construction of the building to lessen the environmental footprint. With over 10% of all construction materials to be regionally sourced from within 500 miles of the project site, the team will significantly reduce waste hauling transportation impact and pollution. Regionally sourced materials will also provide an economic benefit to the area.

The team also has strict plans in place to significantly reduce generated construction waste from area landfills. The suburban site location of the project creates additional challenges in locating waste processors, but the project team has an ambitious goal of diverting over 50% of the all generated waste.

The project design will also include specification and purchase of building materials with over 20% of recycled material content. In some situations, utilizing recycled content requires the sacrifice of aesthetics, but in this case the project actually will utilize the recycled content precast panel materials as a highlighted feature of the

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SYSTEM GROUNDING AND GROUND-FAULT PROTECTION METHODS FOR UPS-SUPPLIED POWER SYSTEMS

Bill Brown, P.E.

The use of solid grounding for UPS-supplied power systems is currently a common practice in data centers. The use of conventional ground fault protection systems in this application can lead to circulating currents and nuisance tripping, resulting in the desire to defeat or exclude ground-fault protection altogether.

This paper explores the nature of circulating currents in UPS-supplied power systems when solid system grounding is employed and the use of modified-differential ground fault protection to eliminate the effects of these circulating currents. In addition, the alternative of high-resistance grounding for this application is discussed, along with its advantages and disadvantages.

THE SOLIDLY-GROUNDED PARALLEL-REDUNDANT UPS SYSTEM ARRANGEMENT

CONDITIONS FOR CIRCULATING CURRENTS

Solid system grounding is commonly employed on parallel-redundant UPS system arrangements such as the arrangement shown in Fig. 1. Three items must be noted regarding this arrangement:

1) The UPS is typically designed so that its output "leads" the utility input by several electrical degrees, in order to insure that when the UPS and utility are paralleled there is a net power flow out of the UPS, which prevents damage to the UPS.
2) The UPS output voltage contains some small level of harmonic content. The source supply voltage also contains some level of harmonic content.
3) The wrap-around bypass system, consisting of circuit breakers CB-4, CB-5, CB-6 and the static switch, may be called upon to parallel the utility source with the UPS in several different situations, such as overload of a UPS module or transfer of the UPS system to maintenance bypass mode.

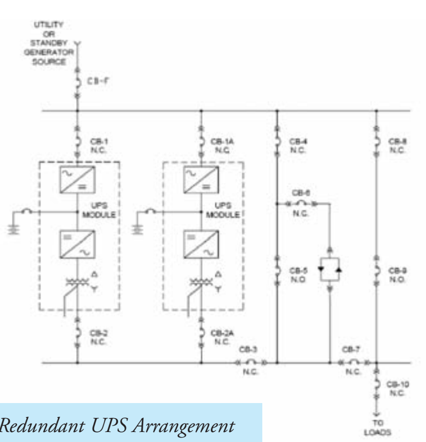

Figure 1: A Parallel-Redundant UPS Arrangement Using Double-Conversion UPSs

Based upon the discussion above, conditions may therefore be present that force the existence of circulating currents, depending upon how the system is grounded.

METHODS FOR ACHIEVING SOLID SYSTEM GROUNDING

One method of achieving solid system grounding is as shown in Fig. 2. Here, the UPS internal details are not shown, and the utility/generator source is shown in a solidly-grounded wye configuration. The UPS output neutrals are connected to a common UPS neutral bus, which is grounded at a single point separate from the utility/generator source. In this configuration, the UPS output is a separately-derived system (note that the NEC definition of a separately-derived system requires that a separately-derived system have no direct connection, even the neutral, with the conductors in another system [1]).

In Fig. 3, the system is in bypass mode with CB-4 and the static switch closed. Such a condition would occur, for example, during automatic transfers to bypass mode due to UPS module overload. The connection between the utility/generator system ground and the UPS output system ground is shown in dotted lines, representing the equipment grounding conductors and grounding infrastructure connections between the two. The circulating current flows, which arise for the reasons outlined above, are shown, with Icp representing the sum of the A, B, and C phase circulating current flows. These divide into two parts, shown as Icp1 and Icp1A, at the two UPS's, recombine at the UPS output neutral bus, and flow back to the utility/generator source over the grounding system. It can be seen that any ground-fault protection incorporated into CB-4 may experience a nuisance trip due to these circulating currents since the net sum of the phase and neutral currents sensed by the circuit breaker is not zero.

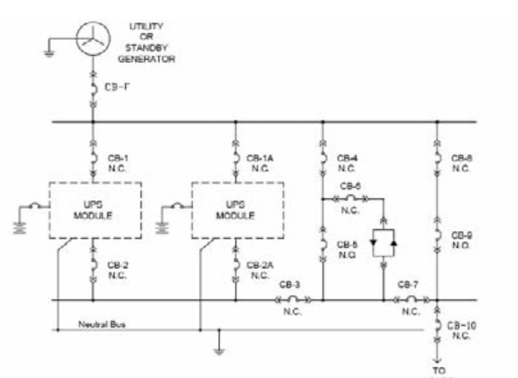

Figure 2: Parallel-Redundant UPS System Arrangement of Fig. 1, with Common Grounding of UPS Outputs

The same applies to CB-F and any other circuit breakers upstream of it, which could result in a wider system outage. Similarly, Fig. 4 shows the ground-fault current flows for a ground fault on the feeder circuit supplied by CB-10. The current IF represents the ground-fault current. It flows along the grounding system from the point of the fault and splits into two components: IF1, which flows in the UPS output system, and IF2, which flows to the utility/generator source. IF1 further subdivides into IF11 and I F11A at the UPS output neutral connections. IF1 and IF2 re-combine at the junction of the CB-3 and the static switch. In practice, a quantitative determination of just how much current flows in the UPS outputs (IF1) vs. the utility/generator source (IF2) is a function of the grounding system impedances and is generally not practical – any ratio between these two currents must be tolerated. It can be seen, then, that for this ground-fault scenario CB-10, if equipped with ground-fault protection, will trip, but CB-4, CB-6, CB-7, and CB-F (and any circuit breakers upstream from CB-F), if equipped with ground fault protection, may also trip since the sum of the phase and neutral currents sensed by these circuit breakers is not zero. A trip of any circuit breaker other than CB-10 would not be ideal. Indeed, if CB-F or circuit breakers upstream from it trip larger portions of the system could be subject to outage. It must be understood that the ground fault scenario of Fig. 4 is only one of several which must be considered.

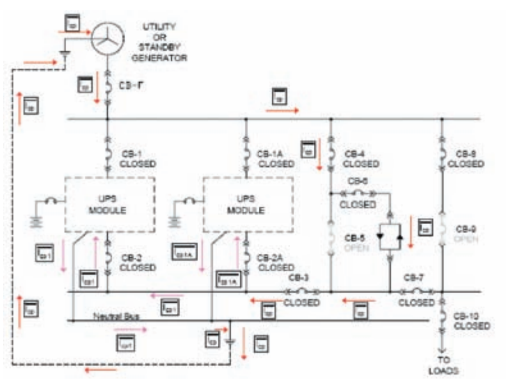

Figure 3: Circulating Current Flows for Grounding Arrangement of Fig. 2

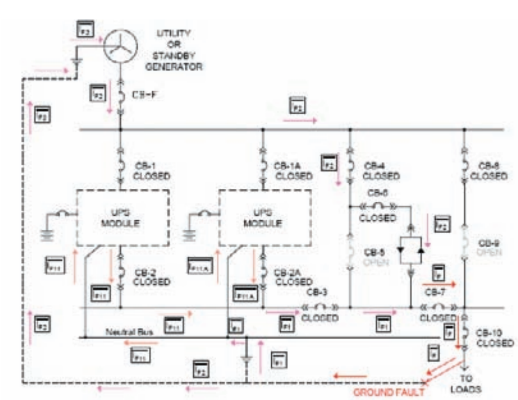

Figure 4: Ground Fault Current Flows for Ground Fault as Shown, Grounding Arrangement of Fig. 2

Clearly, the grounding arrangement of Fig. 2 is not ideal, from the standpoint of the use of conventional radial ground-fault protection. One response to the ground-fault performance issues is to change the grounding system arrangement. One common arrangement, which is intended to reduce ground-fault nuisance tripping issues, is that of Fig. 5. In Fig. 5, the UPS output neutral bus is not separately grounded, but has a solid neutral connection back to the utility or standby generator system neutral. The UPS output in this arrangement, by definition, is not a separately-derived system.

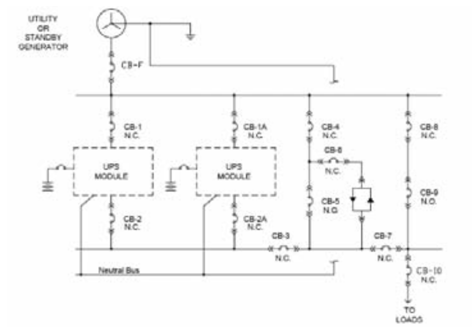

Figure 5: Parallel-Redundant UPS System Arrangement of Fig. 1, with Neutral Connection to Utility or Standby Generator Source

The performance of the grounding arrangement of Fig. 5 when subjected to circulating neutral currents is shown in Fig. 6. Here, it can be seen that circuit breakers equipped with ground-fault protection will not be sensitive to circulating current flow, since the neutral currents are such that the total current seen by the ground-fault protection on any circuit breaker is zero. So far, so good. However, consider the ground-fault depicted in Fig. 7. Here, the ground fault is located between circuit breakers CB-4 and CB-6. As can be seen, any ground-fault protection provided on CB-4 will sense the correct current (phase + neutral current = IF1 + IF2 = IF) and trip. However, the fault is also supplied through CB-6, which will sense no ground-fault current (phase + neutral current = IF1 – IF1 = 0). Any ground-fault protection for CB-6 is therefore defeated for the fault location shown.

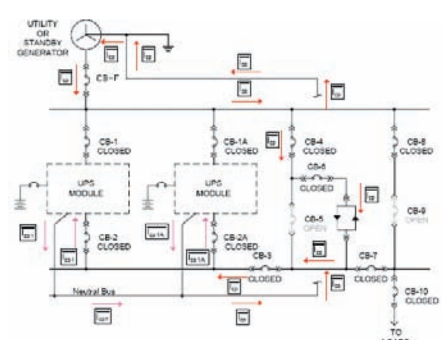

Figure 6: Circulating Current Flows for Grounding Arrangement of Fig. 5

As with the previous grounding arrangement, this is but one of many ground-fault scenarios which must be accommodated if ground-fault protection is supplied on the UPS system circuit breakers. Clearly, as with the previous arrangement, this arrangement is not optimal insofar as ground-fault protection is concerned, although it does have the advantage of de-sensitizing the ground-fault protection to circulating currents that occur during normal operating conditions.

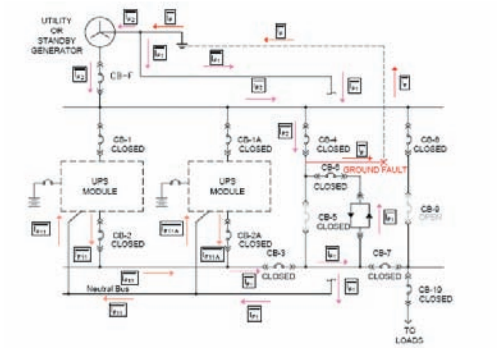

Figure 7: Ground Fault Current Flows for Ground Fault as Shown, Grounding Arrangement of Fig. 5

THE SOLUTION TO THE GROUND-FAULT PROTECTION PROBLEM

As stated previously, it is not the intent of this document to argue whether ground-fault protection is required for the UPS system output. It has been argued [2] that omitting such protection increases the risk of damage, increasing the mean time to repair (MTTR). However, even that argument is not the subject of this paper. The issue at hand is if the UPS system is solidly grounded, and if ground fault protection is desired (regardless of the justification), how can it be achieved?

The solution is a differential ground-fault protection scheme, popularly known as modified-differential ground-fault protection or MDGF. This type of ground-fault protection scheme divides the system in to protective zones. Within each protective zone, the correct protective devices trip to isolate the ground-fault condition to the smallest possible part of the system. If properly designed, the MDGF scheme also makes the ground-fault protection immune to the effects of circulating currents. An example of the protective zones for such a scheme, as applied to the system of Fig. 2, is shown in Fig. 8:

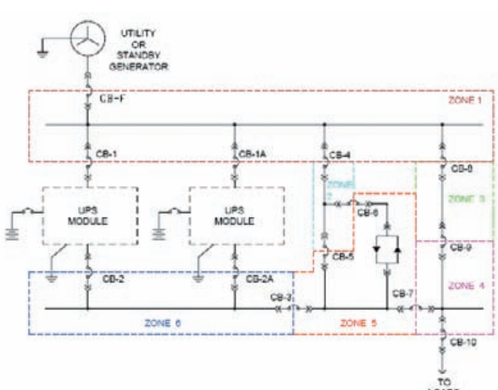

Figure 8: Example MDGF Protective Zones for System of Fig. 8

In Fig. 8, the system has been divided in to six protective zones. The devices that would trip for a ground fault in each zone are shown in Table I:

Zone	CB-F	CB-2	CB-2A	CB-3	CB-4	CB-5	CB-6	CB-7	CB-8	CB-9	CB-10
1	X				X				X		
2					X	X	X				
3									X	X	
4								X		X	X
5				X		X	X	X			
6		X	X	X							

Table I. Devices to Trip for a Ground Fault in Each Protective Zone of Fig. 8

The protective zones shown give optimum isolation of a ground fault, i.e., the minimum part of the system is disturbed should a ground fault occur. Other arrangements are possible, depending upon the level of isolation desired. It should be noted that CB-1 and CB-1A do not appear in Table I; since there is no possibility of those two circuit breakers feeding a ground fault in the zones under consideration.

The hardware implementation of the MDGF scheme is generally accomplished with additional current sensors and auxiliary protection hardware that interfaces with the electronic circuit breaker trip units. For example, to accomplish the ground-fault protection for Zone 1 of Fig. 8, the arrangement of Fig. 9 could be used. Each of the current sensors shown represents either a zero-sequence current sensor or individual phase and neutral current sensors. The devices "F", "4", and "8" represent the auxiliary protection hardware that interfaces with the electronic circuit breaker trip units for CB-F, CB-4, and CB-8, respectively. In practice, sensors are shared between zones, resulting in sensor interconnections that make the most effective use of the sensors.

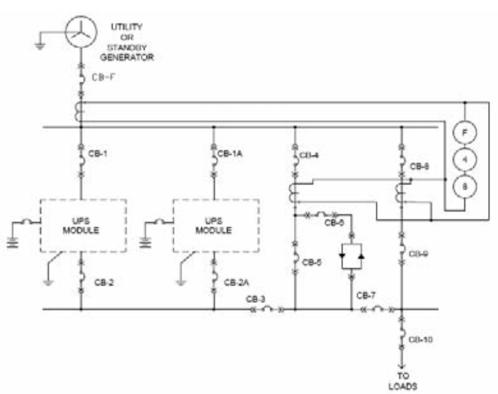

Figure 9: One Arrangement for Achieving MDGF Protection of Zone 1 of Fig. 8

More information regarding MDGF schemes may be found in the literature ([2], [3]). In practice, a custom design is often required to achieve the objectives above for the grounding arrangement desired. However, MDGF can usually be implemented in a cost-effective manner, allowing the use of ground-fault protection without the issue of nuisance tripping or de-sensitization.

UTILIZING HRG WITH THE PARALLEL-REDUNDANT UPS ARRANGEMENT

APPLICATION OF HRG TO THE PARALLEL-REDUNDANT UPS ARRANGEMENT

One potential work-around to the issues which affect solidly-grounded system is to use HRG. Typical implementation of HRG to the parallel-redundant UPS arrangement is shown in Fig. 10:

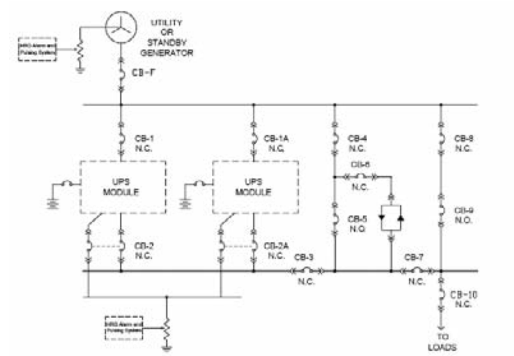

Figure 10: Application of HRG to the Parallel-Redundant UPS Arrangement

In Fig. 10, both the utility/generator source and the UPS outputs have HRG applied. This is to be expected, since the two could be paralleled via the static switch and CB-4, CB-5, and CB-6 as described previously; it is not desirable to parallel a solidly-grounded system with an HRG system. The UPS output neutral connections are brought to a common neutral bus in the output switchgear, where they are grounded through the HRG resistor. Ground-detection alarm and pulsing systems allow detection and location of ground faults, without the need to trip since the fault currents are at a very low level (1-10A).

The UPS output circuit breakers CB-2 and CB-2A are shown as 4-pole circuit breakers. The reason for this is that the voltage at neutral outputs during a ground-fault condition can have a voltage which is up to the nominal line-to-ground voltage (277V for a 480V system). Because a ground-fault condition can exist continuously on such a system, the neutral poles of these circuit breakers allow complete isolation of their respective UPS units for maintenance. Using 3-pole breakers would allow the exposure of maintenance personnel to hazardous voltage should a ground fault exist on the system.

As discussed previously, any circulating currents in the ground system which arise due to paralleling the UPS outputs with the utility or generator source are greatly reduced due to the ground resistors. Therefore, circulating ground currents during normal conditions are not normally a problem in these types of systems. Should a ground fault occur while the UPS output and the utility/generator sources are paralleled, the HRG resistors, because they are much larger than the other impedance elements in the ground path, cause the ground fault current to divide approximately equally between the two sources.

IS THERE A DOWN-SIDE TO HRG?

Thus far, the description of the application of HRG to the parallel-redundant UPS arrangement has mentioned no negative aspects. In reality, there is no "perfect" solution and there are consequences to the use of HRG in this arrangement, namely:

- Added expense of pulsing systems and 4-pole circuit breakers where required
- Larger equipment size to accommodate HRG resistors, pulsing systems and 4-pole circuit breakers where required
- Limited use of TVSS (typically no phase-to-ground modes of protection)
- Care must be used in selecting load equipment to insure it is compatible with the HRG arrangement (phase-to-ground voltage can be up to 173% of its nominal value during a ground fault)
- A second phase-to-ground fault which occurs before the first is cleared will result in a phase-to-phase fault, with a trip required to clear it.
- The system cannot serve 4-wire loads without using transformers to establish solidly-grounded separately-derived system

The last limitation is usually not an issue in this application, since the UPS system usually supplies several Power Distribution Units (PDU's) which contain delta-wye transformers. All of the load equipment (computers and IT equipment) is connected to the solidly-grounded system at the secondaries of these transformers (typically 208Y/120V).

The point regarding load equipment, however, can be a significant limiting factor. Such "load equipment" includes the UPS modules themselves; it should always be confirmed that the UPS proposed for such an installation can coexist with the HRG system.

SUMMARY

In this paper, the various aspects of solidly-grounded systems when employed for the parallel-redundant UPS arrangement have been examined. In general,

- Solidly-grounded systems are the most common.
- Circulating currents that exist in the parallel-redundant UPS arrangement when solidly-grounded systems are used make the application of conventional ground-fault schemes impractical.
- If ground-fault protection is required for a solidly-grounded parallel-redundant UPS system, a modified-differential ground fault (MDGF) protection scheme must be employed.
- HRG is an alternative means to ground such systems, but is not a "perfect" solution, and trade-offs must be accepted if HRG is used.

The grounding scheme to be used must be given careful consideration for the resulting system to provide the required level of reliability. If designed properly, either a solidly-grounded or HRG system arrangement can provide reliable, stable systems which fulfill the expectations of high reliability and maintainability.

REFERENCES

[1] NFPA 70, 2005 National Electrical Code, Quincy, MA: NFPA
[2] M. Mosman, R. Tajali, "Optimizing Power System Protection for Data Centers", Pure Power, September 2003
[3] Swindler, D.L., "Elegant Ground-Fault Solutions for Impossible Problems", IEEE Transactions on Industry Applications, Vol. 37, No. 1, pp. 117-128, January/February 2001.

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ASSURING THE RELIABILITY OF CRITICAL POWER CABLE SYSTEMS AT THE LOWEST COST

Benjamin T. Lanz

Critical facility engineers are required to provide a safe and reliable electrical cable infrastructure that will assure maximum uptime at the lowest cost. Engineers assigned this responsibility are able to make better power cable system reliability decisions when effective predictive diagnostic tools are applied. Many in the industry are not aware that the IEEE no longer fully supports high potential withstand tests as an acceptance test for shielded power cable systems, and are unknowingly putting their systems at risk. This paper is an overview covering the latest IEEE standards and best practices for specifying modern cable systems and applying predictive diagnostics to industrial shielded extruded dielectric cable systems rated 5kV and higher. Case studies from actual critical facilities will demonstrate the ability of modern defect specific diagnostics (DSD) to repeat the manufacturers test in the field, pinpoint defects, and avoid future unplanned service outages.

According to recent industry discussions, there is an increased demand for critical facilities to operate reliably and safely while cutting costs by extending the traditional maintenance cycle. The forces of higher reliability and longer maintenance cycles are diametrically opposed and thus, cost reductions require asset managers to have access to better, more predictive information to facilitate cost effective actions. The vital links of shielded power cable infrastructure are no exception.

BACKGROUND ON CABLE SYSTEMS

Medium voltage power systems most widely used in commercial and industrial installations are composed of cables with extruded insulation, such as crosslinked polyethylene (XLPE) and ethylene-propylene rubber (EPR), and cables with laminated insulation, i.e. fluid-impregnated paper-insulated lead-covered (PILC). These cables, which power vital processes, are installed underground and in cable trays throughout commercial and industrial facilities. The cable systems range from 5kV to 35kV. As cables and their accessories age, their propensity to fail in service increases. Experience obtained while conducting predictive diagnostic evaluations of over 12,000 miles of cable demonstrates that cable deterioration manifests itself through discrete defects. Some examples of discrete cable insulation defects are electrical trees, water trees eventually leading to electrical trees, impurities, delamination of semi-conducting screens, protrusions in extruded insulation, and carbonized tracking in laminated insulation. Accessories, on the other hand, typically fail because of poor workmanship, contamination, or moisture ingress along interfaces within the cable insulation. Many in the industry are surprised to learn that modern extruded cable systems are not likely (less than 1% of time) to fail due to conduction, otherwise known as the proverbial electrical "leakage". Although there are many scenarios which can initiate the process that will eventually cause the insulation of modern extruded cable systems to fail, there is one common symptom. The vast majority of failure mechanisms (>95%) are associated with a process known as partial discharge (PD). This failure mechanism causes the insulation to be eroded over time until a fault channel bridges its entire thickness. Partial discharge and its importance to leading edge defect specific diagnostic technology will be thoroughly discussed in the following sections of this paper.

HISTORY OF CABLE TESTING

During the last century, cable acceptance tests have traditionally been carried out by applying a direct current (DC) voltage to a cable at a specific voltage level and for a prescribed duration. The DC high potential withstand test, or DC HIPOT (an IEEE Type 1 Destructive Withstand Test), was a reasonable test for paper insulated lead covered (PILC) cables due to the significant percentage of defects associated with an increase in insulation conductivity (approximately 40%). The DC test can only detect the types of defects which are associated with conduction and present themselves in the form of power loss or "leakage current." Today we know that as much as 70 to 80% of defects in these older type cable systems fail in association with the aforementioned electrical phenomenon known as partial discharge. Thus, partial discharge measurements are very useful for aged paper insulated systems. When extruded dielectric cable (i.e.HMWPE, XLPE, EPR) was introduced in the 1960s, the cable manufacturers were aware that the primary failure mechanism of this type of insulated cable was partial discharge (over 95%). While the factory partial discharge test (known as a corona test back in the '60s) was able to detect partial discharge in cable, it involved expensive equipment and required a fabricated electromagnetically shielded environment to conduct the test. Even though the DC HIPOT was known to manufacturers to be highly ineffective, the complexity of the PD test all but assured that the field test industry would continue to use the widely available and most recognized DC test. In fact, "from the work of Bach (TU Berlin), we know that even massive insulation defects in extruded dielectric insulation cannot be detected with DC at the recommended voltage levels." (IEEE 400, section 4.2) For some time the industry experimented portable alternatives to the DC test such as very low frequency (VLF) AC, however "a major objection to Type 1 field tests is the concern that application of elevated voltages without any other accompanying diagnostic measurements trigger failure mechanisms that will not show during the test but which may cause subsequent failures in service." (IEEE 400, Section 4.3) These challenges left a significant void in the industry's ability to effectively test new or existing shielded power cable systems until the mid-nineties when Dr. Matthew Mashikian, an innovative engineering professor at the University of Connecticut, was able to utilize evolving digital signal processing technologies to solve the shielded room/field noise dilemma and develop a PD test technology to replicate the cable manufacturers' factory test in practical field applications. This technology, known as off-line 50/60 Hz partial discharge diagnostics, has been developed over the past 12 years in the utility industry and has evolved into a robust condition assessment and predictive diagnostics solution for power cable systems.

PARTIAL DISCHARGE DIAGNOSTICS

The IEEE Type 2 off-line 50/60 Hz partial discharge diagnostic test, otherwise known as defect specific diagnostics (DSD), offers a major advantage over traditional IEEE Type 1 DC and AC destructive withstand test, because it enables the cable owner to predictively pinpoint the exact defect location, providing the details necessary to take precise action without destroying the cable. During its service life, a cable is subjected to overvoltage conditions caused by switching, lightning, and other transient events. Any test conducted at operating voltage will be unable to simulate in the cable system the conditions which may produce partial discharge during operation. Therefore, in order to effectively predict the future performance of the cable system, a partial discharge test at a reasonably elevated voltage must be conducted, as stipulated by IEEE ICEA, and IEC. Hence, each component of the system, the cable, joints and terminations have their own acceptable level of discharge (see Table 1 below) defined by IEEE and ICEA. Since the off-line 50/60 Hz partial discharge diagnostic approach is non-destructive and predictive, it represents a significant breakthrough for critical facility engineers who are required to provide a safe and reliable electrical cable infrastructure. The technology enables engineers to specify and quantify cable system installation quality levels on a component by component basis. Armed with this foot by foot profile, engineers can now hold contractors to task for substandard workmanship prior to the end of the warranty period. The baseline profile provided by this technology is also a powerful tool for asset managers. Once a system is installed and each system component is proven to meet industry standards, the baseline profile can be compared to subsequent diagnostic tests. Asset managers can use trending information as a factual condition basis to optimize and extend the period between maintenance cycles.

IEEE 400 section 7.4 states that "if the cable system can be tested in the field to show that its partial discharge level is comparable with that obtained in the factory [off-line 50/60 Hz PD diagnostics test on the cable and accessories], it is the most convincing evidence that the cable system is in excellent condition."

TABLE 1
STANDARDS AND SPECIFICATIONS

STANDARD	SPECIFICATION*
IEEE 400.3	pC Calibration/Sensitivity Assessment Procedure
IEEE 48 Terminations	No PD ≥ 5pC up to 1.5Uo
IEEE 404 Joints	No PD ≥ 3pC up to 1.5Uo
IEEE 386 Separable Connectors	No PD ≥ 3pC up to 1.3Uo
ANSIICEA S-97-682-2007 MV Cable	No PD ≥ 5pC up to 4Uo**

**Uo is the cable system's operating voltage, **200V/mil*

CASE STUDY I

A petrochemical plant was experiencing an average of 1 failure every 3 years leading up to a off-line 50/60Hz PD diagnostic test. On a regular basis, all of the plant cables were subjected to an IEEE Type 1 destructive DC HIPOT maintenance test. These tests were performed according to IEEE recommendations prior to the latest revision in 2001. The cables routinely passed the DC test but continued to fail in service. Fault records and subsequent off-line 50/60Hz PD diagnostics confirmed that the terminations were the weakest points on the system. After performing the off-line PD diagnostic test, the results were then used to make specific repairs to the 40 defective terminations, 9 defective splices and 3 defective cable spans. If the failure rate prior to the off-line PD diagnostic tests and repairs had continued, this plant would have experienced 2 more costly unplanned outages to date. Since the off-line 50/60Hz PD diagnostic test in 2000, the site has not experienced a single failure and the maintenance test cycle was stretched from once per year to once in nine years. This case study illustrates how a plant owner can maximize reliability while significantly lowering maintenance costs.

CASE STUDY II

The critical shielded power cable systems linking a substation with a power generation plant were commissioned using an off-line 50/60Hz PD diagnostic test. Twelve cable terminations on the substation end of the circuits where found to be performing well below the industry specifications in Table 1. The contractor, being unfamiliar with the latest diagnostic technology and industry standards, insisted that the terminations were installed correctly. In an ill-fated attempt to prove a point, the contractor performed and IEEE Type 1 VLF 0.1Hz Destructive AC HIPOT on all of the cable systems in question. All cable systems passed the VLF AC HIPOT. Within one month, one of the terminations recommended for repair by the off-line 50/60Hz PD diagnostic test failed (see Figure 1). The contractor was forced by the plant owner to concede and repair all the substandard terminations. This case study is only one instance but, it is typical of many others which are playing out across the industry in which the off-line 50/60 Hz PD diagnostic technology is putting plant engineers in the driver's seat of the quality assurance process.

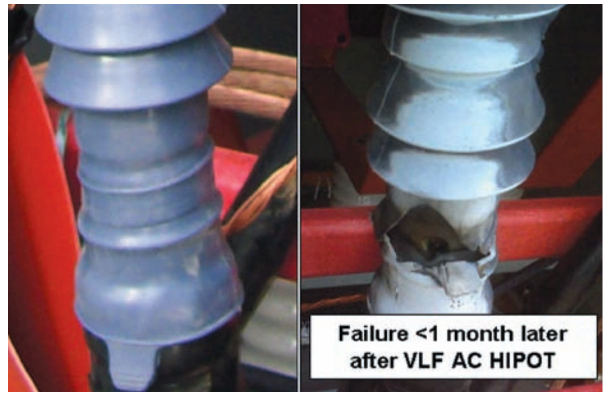

Figure 1 Cable Termination with Substandard Performance (left)
Cable Termination with Failure Less Than 1 Month Later

CASE STUDY III

A cable owner was interested in comparing off-line PD diagnostics with on-line PD diagnostics on a 35 year-old critical circuit. The on-line test had the advantage of not having to take the line out of service. The owner first requested an off-line 50/60Hz, PD diagnostic test to be performed on the 630ft long, 15kV class, extruded cable. According to the PD diagnostic test results and the industry specifications in Table 1, there were 13 defects in the cable insulation and one defect in a joint. The defect in the joint was found to have PD at only 80% of the operating voltage stress level which means that it was most likely under continuous PD conditions. Refer the PD test results in Figure 2 below. Even though the cable system was recommended for replacement, for experimental purposes, the cable system was temporarily put back in service.

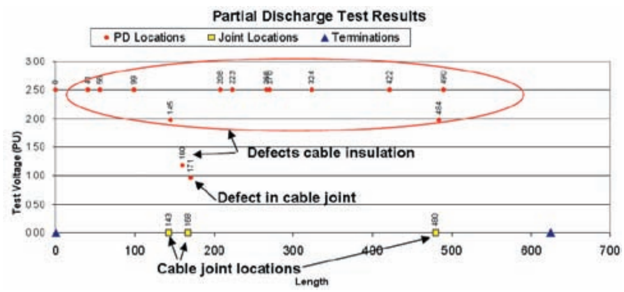

Figure 2 Off-line 50/60Hz PD Diagnostic Test Results

The on-line PD test technician was not given the off-line test results. The on-line test technician applied the sensors at the terminations of the cable. Using proprietary sensors, a spectrum analyzer, and a special noise filtering process, the mobile on-line testing unit was not able to detect any PD activity in the cable system. The on-line PD test report stated that the cable was free from defect and should be left in service. In this case study, the superior accuracy and value of the off-line 50/60Hz PD diagnostic test clearly illustrates how engineers responsible for critical cable systems can use advanced technology and the latest industry standards to make condition based strategic decisions and maximize the reliability of aged assets.

CONCLUSION

In order to assure the reliability of critical power cable systems at the lowest cost, engineers need a predictive technology which gives complete and factual condition based information. This paper has provided an overview of the latest IEEE standards and applying predictive diagnostic industrial shielded extruded dielectric cable systems rated 5kV and higher. Case studies from actual critical facilities have demonstrated off-line 50/60Hz PD defect specific diagnostics have the ability to repeat the manufacturers test in the field, pinpoint defects, avoid future unplanned service outages and assure liability while extending the maintenance cycles and saving precious operating and maintenance dollars.

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HUMIDITY CONTROL

Current data center HVAC design methods are incorporating different paradigms today than were prevalent in the past. The philosophy of precision air conditioning utilizing CRAHs has been supplemented by new approaches utilizing large air handling systems with underfloor and even overhead air distribution. The increasing equipment load densities are overtaking the design philosophies of the past. Increasing awareness of the huge energy usage of the typical data center and the subsequent large investment in data center power and cooling infrastructure has forced owners, designers and builders to develop new approaches. One new concept has been to provide a single system of humidity control which incorporates energy saving technologies. This has impacted the HVAC design to allow more flexibility in equipment and system selection to include air side economizers and dedicated outdoor air handling systems for makeup ventilation air supply.

ASHRAE GUIDELINES FOR DATA CENTER ENVIRONMENTS

ASHRAE has developed a new, less restrictive range of temperature and humidity values for the air entering the IT equipment racks within the data centers. Class I facilities with enterprise servers and storage equipment mounted in racked cabinets arranged in rows have the most restrictive conditions. The previous thermal envelope was developed when the use of wide format open reel tape drives; printed paper products and punch cards were prevalent. Tight humidity levels had to be maintained in order to prevent tape failure, paper feed jams and card deterioration. The new environmental envelope has been developed by an industry wide team including hardware manufacturers, environmental equipment manufacturers, consultants and operators of large scale centers based on extensive discussion and collaboration. The recommended conditions were formerly 20 to 25°C (68 – 77°F) and 40 to 55% relative humidity (RH). The new recommended values are 18 to 27°C (64.4 to 80.6°F), dewpoint of 5.5 to 15°C (41.9 to 59°F) and a maximum relative humidity of 60% RH. The inclusion of dewpoint values is significant in that it will provide increased ability to maintain a constant humidity ratio in the space. It will also reduce the possibility of operation of the centralized humidification when the space is already at an acceptable humidity ratio.

IMPORTANCE OF HUMIDITY CONTROL IN DATA CENTERS

Humidity control is important in data centers to provide optimal operation of IT equipment in terms of both a high limit range and a low limit range. The high limit value is established to prevent conductive films from forming on printed circuit boards and also to prevent corrosion in disk drive heads and magnetic tape drives. Low humidity levels are associated with the risk of electrostatic discharge (ESD). The low limit value measured as dewpoint in lieu of relative humidity is implemented to provide a simpler control approach since cooling processes at the lower portion of the range are purely sensible cooling processes. Both the low limit and high limit values are based on industry research and ASHRAE is continuing research into moisture levels and ESD risks as they affect IT equipment and operations.

HUMIDITY LOADS IN DATA CENTERS

Today's data center is constructed in a location that is usually selected based on electric utility rates, geological hazard and weather hazard minimization. Little thought is given to weather trends and average environmental conditions. The HVAC system should be selected to take advantage of local weather trends and conditions. The ventilation of the data center is gaining more attention as codes and energy efficient rated construction gain traction. The LEED rating system has also gained influence as owners desire to exhibit a strong corporate evidence of attention to sustainable construction.

The common data center has little variation in space humidity levels. Facilities are designed so that the building envelope has a low permeability vapor barrier in the roof walls and floor structure to minimize water vapor intrusion into and out of the space. The other common source of moisture is people. The data floor typically will have a very low density of personnel. Therefore the contribution of people to the moisture load within the space is minimal.

METHODS OF CONTROL

This issue has resulted in designs which utilize a dedicated outdoor air system (DOAS) to provide a single air handling source of conditioned and humidity controlled air to the space. The humidity controlled make up air system is easily capable of maintaining humidity levels within the space that are in compliance with ASHRAE's recommended levels. The system is also capable of providing building pressurization control to minimize infiltration of uncontrolled and unfiltered air into the space. This system is utilized in locations with high variability and high average outdoor humidity levels.

Another design incorporates 100% outside air economizers to take advantage of both the wider recommended environmental envelope and the local weather conditions as appropriate to provide nearly free cooling. The primary advantage of this system is reduced chiller operation.

IN DATA CENTERS

John Eagar, PE

Economizer control is provided by comparison of outside air to return air enthalpy. Humidity is based on supply air conditions and return air dew point. In addition, evaporative media systems are included to provide humidification and temperature control with reduced chilled water usage.

Sensors used in humidity control are primarily electronic, utilizing resistance or capacitance measurements of polymer materials whose electrical characteristics vary with relative humidity moisture content of the ambient air. Newer technologies include utilization of optical sensing of moisture on a chilled mirror whose surface temperature at condensation is the dewpoint, and infrared absorption sensing of moisture content in the air. Other types of sensors include aluminum oxide sensors which utilize the linear relationship of capacitance across a dielectric to measure moisture content. These newer types are more expensive than the resistance polymer film type but costs are lowering as they are accepted more in the marketplace. They are also utilized in the calibration of other less accurate sensors. Calibration of humidity sensors is critical to their proper control output and should be performed on a regularly scheduled basis. Utilizing an array of sensors in the controlled space will provide the operator with a method of determining calibration faults out of tolerance and assist in recalibration of signal outputs. Space humidity as measured by dew point should be uniform across the data floor when a single source of control such as a DOAS unit provides make up air and when the cooling process is 100% sensible. If the cooling has less than a 100% sensible heat ratio, the moisture taken out must be replaced. (This is why it is important to use a high supply temperature.) High limit sensors at the humidification source should be provided to limit the impact of overrun of humidification into a saturated air condition.

HUMIDIFICATION METHODS

Data center humidification can be provided by several different methods. The basic goal is to provide air conditions at a fixed dew point of 10ºC (50ºF). This value is a humidity ratio in the central area of the ASHRAE conditions envelope. The larger range of acceptable dewpoint conditions above and below this value allows reduced water usage and dehumidification loads on the central plant.

Individual CRAC units should not have stand alone control of humidification and dehumidification. CRACs with supply air temperature control will provide sensible cooling only to the space at the elevated supply air temperatures recommended by ASHRAE. Also, these higher temperatures allow the increased use of elevated chilled water temperatures and allow more hours of economizer operation which are two methods of significantly reducing overall energy usage in the data center. Individual CRAC units, if provided with humidity control, should operate based on a common reference signal.

Air handling systems providing make up air or outside source economizer air can utilize several different means of humidification.

These include adiabatic types which require no addition of energy from external sources. The adiabatic humidification methods include evaporative humidifiers and evaporative coolers utilizing rigid media. One inherent advantage to this type of humidification is the filtration and scrubbing effect of the air. Also, this type of system can provide cooling and humidification simultaneously. The water utilized in this method must be flushed periodically to remove the contaminants removed from the airstream. This type is scalable to large volume air handling systems and is the preferred choice when large air side economizers are included.

Another method that is gaining wider acceptance is ultrasonic humidification. This utilizes a piezoelectric transducer in demineralized water to atomize the water, resulting in water vapor injected into the supply airstream. This method is recognized as being the most energy efficient. However, cost of this type system is higher relative to other types and there are capacity limits for systems currently available in the marketplace.

A third method used for low volume applications is the electrically heated self contained humidifier utilizing submerged electrodes to produce steam which is than injected into the airstream utilizing a distribution manifold. This system also requires a periodic flushing action to remove solids deposited by evaporation.

Heated pan humidifiers are the standard method utilized in individual CRAC units by their manufacturers. These systems utilize either infrared heaters or steam or hot water heat exchangers to provide the energy to supply water vapor to distribution manifolds.

Direct injection steam humidifiers are another method. The steam source is a central steam boiler which is also utilized for facility heating. One caution when using this method is that the chemicals used in treating the boiler system affect indoor air quality and make this application less desirable than others.

DEHUMIDIFICATION METHODS

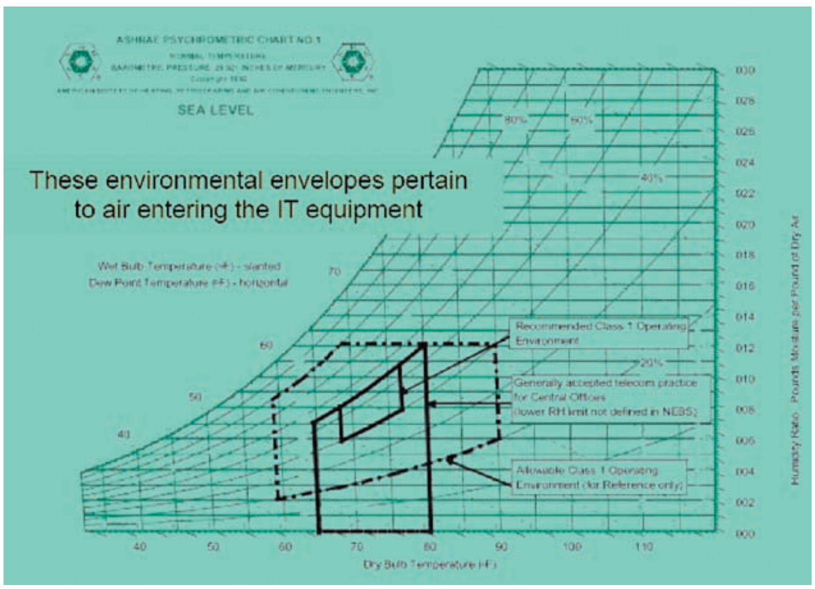
Dehumidification loads of data centers are primarily the removal of moisture of outdoor ventilation air.

Conventional chilled water cooling systems utilizing 7.2°C (45°F) supply water inherently control dew point of the air circulating within the space to a dewpoint of 10 to 12.2°C (50 to 54°F). However, the central chilled water plant energy usage in maintaining this low chilled water temperature can be reduced by raising the supply temperature of the air handling system. When this is done the dehumidification capability is lessened and the cooling coils become 100% sensible capacity only. The energy savings can be significant and more than offset the cost of supplemental dehumidification equipment, especially when a DOAS system is utilized. There are several methods of dehumidification available from the HVAC industry that are tried and proven effective.

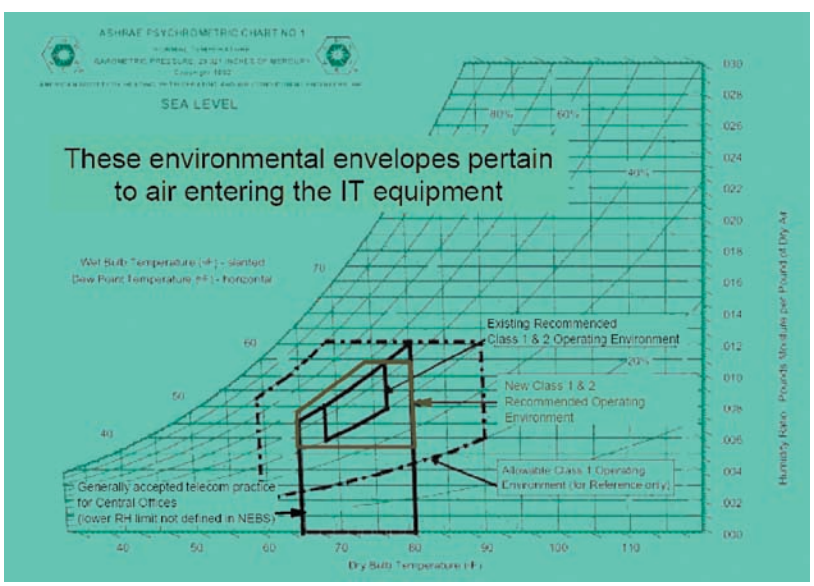
If a chilled water cooling/dehumidifying coil incorporated into a DOAS air handler is utilized, several methods are available for increasing the dehumidifying capacity without an accompanying increase in energy usage to subcool the air. These include coil to coil heat reclaim utilizing two refrigerant coils in a wraparound configuration. One coil is upstream of the dehumidifying coil and precools the air stream. The heat absorbed by this upstream coil is then transferred to a coil downstream of the dehumidifying coil and reheats the air above the saturation temperature and more closely matches the space temperature. This reduction in entering air temperature to the dehumidification coil increases its latent or dehumidification capacity.

Dessicant dehumidifiers are available as both dry and wet media types which are incorporated into a DOAS system. The desiccant is embedded in a wheel which constantly is reactivated from a heat source internal to the unit. They are also available in energy saving configurations utilizing air to air heat recovery which reclaims exhaust air heat to reactivate the media which becomes saturated with moisture over time. Dessicant systems also supplement air filtration systems by removal of VOCs and airborne microorganisms. Dessicant dehumidification is sometimes difficult to implement in data center applications due to the low rate of exhaust in the space.

Direct refrigerant cooling/dehumidifying coils are available in package air handling units. These systems can utilize hot gas reclaim to reheat the coil above the saturated leaving conditions.



Prior ASHRAE TC 9.9 Thermal Guideline for Data Processing Environments

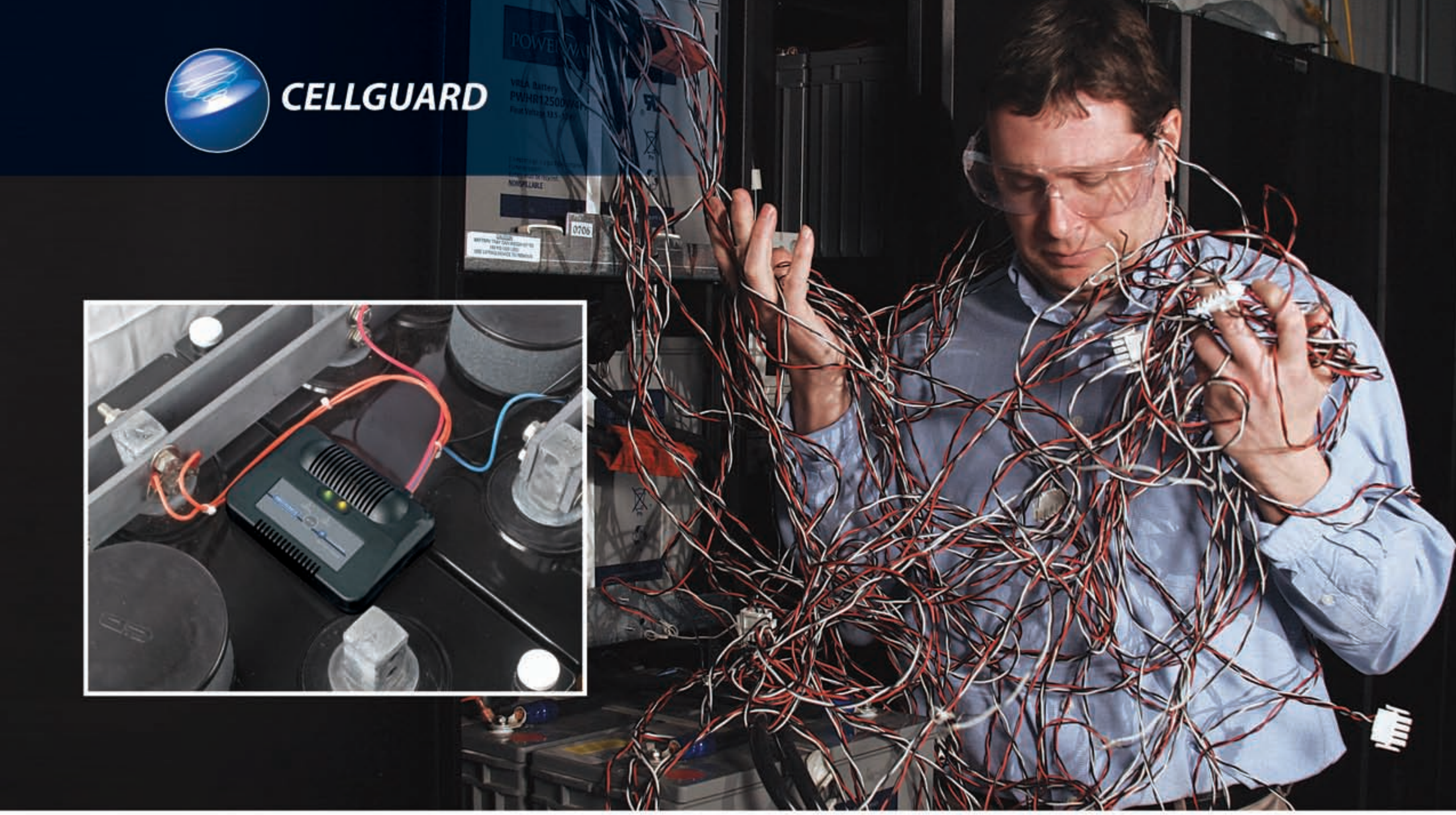


Updated ASHRAE TC 9.9 Thermal Guideline for Data Processing Environments

CONCLUSION

The new ASHRAE Thermal Guidelines provide a wider range of temperature and humidity in the data center environment. This is useful in today's energy environment and results in significant opportunities for reduced energy usage through implementation of economizer operations strategies. The shift of control of humidity in the space from multiple CRAC units to a single controlled source improves energy usage and reliability as well.

John Eagar, PE is as Associate Partner at Syska Hennessy Group. He can be reached at jeagar@syska.com.



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INNOVATION TECHNOLOGY QUALITY WORLDWIDE

GREEN BUILDING FIRE PROTECTION TECHNOLOGY

Kate Houghton

Incorporating green fire safety into modern buildings is an increasing priority for building owners. Advances in the area of fire detection technology as well as fire suppression systems have, in recent years, made the goal of "greening" facility fire safety systems more attainable. These advances are also reflected in the ongoing development and updating of international and national codes and standards, an important consideration when selecting the correct fire safety system for green building and facilities. The ability to obtain LEED (Leadership in Energy & Environmental Design) credits by installing environmentally friendly fire protection is a welcome boost in seeking the overall LEED classification of a new building or building retrofit. Fire protection plays an important role in overall building design and construction. Building owners and fire protection engineers alike need to be able to navigate the complex waters governing code compliance, LEED certification and system suitability for the hazard being protected.

FIRST STEPS

In determining which fire protection system is correct for your green building it is important to make a thorough analysis to identify the critical physical areas of operation and function. Business continuity and the ability to return quickly to normal operations is vital today, because uptime is at a premium and excessive downtime can herald the untimely demise of an otherwise healthy business. Building areas that are critical to daily business functioning may include data centers, control rooms, power generation facilities, plant rooms or flammable liquid storage areas. A buildings operation can be crippled if any of these areas is rendered inoperable by fire. Areas that provide key day-to-day functionality for the building demand fire protection above and beyond the minimum regulated requirements such as sprinkler systems and portable extinguishers.

Once an area is identified as critical and requiring additional protection, the next step is to perform a multi-faceted hazard analysis. Understanding potential types of fires and potential ignition sources within any building area is vital to the correct selection of both detection and suppression technology. Differentiating between class A (combustible materials such as paper or plastics) and class B (flammable liquids) is important as this will aid in selecting the most efficient detection and suppression technology for every hazard in the building. Thoroughly reviewing the potential sources of ignition will allow not only for correct fire protection system selection, but also for possible elimination of these sources. For example, good housekeeping can eliminate some likely fire hazards. Upon completing the hazard analysis the fire protection engineer, building owner or other responsible party needs to determine the applicable codes and standards that apply to the facility as well as the best choices for fire protection systems. As a fire protection system comprises of both fire detection elements and fire suppression elements, it is likely that multiple standards will apply.

CODES AND STANDARDS

The three most relevant national codes that relate to fire protection systems found in green buildings are published by the National Fire Protection Association and include: NFPA 72, NFPA 2001 and NFPA 750. While these codes are not mandatory in all jurisdictions they are worth following as they are written to provide maximum life safety to property and personnel. A brief discussion on each of these standards follows.

NFPA 72 – National Fire Alarm Code

The National Fire Alarm Code governs the design, installation, operation and maintenance of fire detection and fire alarm systems. It includes requirements for detector spacing, occupant notification and control panel functionality.

NFPA 2001 – Standard on Clean Agent Fire Extinguishing Systems

The Standard for Clean Agent Fire Extinguishing Systems governs the design, installation, operation and maintenance of clean agent systems. It includes requirements for determining design concentrations, for safe personnel exposure levels and system discharge times. This standard also requires an agent to be included on the US EPA SNAP list (and being accepted by the EPA on environmental grounds) before it can be included in the document.

NFPA 750 – Standard on Water Mist Fire Protection Systems

The Standard on Water Mist Fire Protection Systems is the governing standard on classification of water mist system types, and includes requirements for design, installation, operation and maintenance of water mist systems.

LEED CONTRIBUTION BY FIRE PROTECTION SYSTEMS

The choice of fire suppression systems is currently reference only indirectly within the LEED certification program documents. The New Construction (NC) v2.2 – Energy and Atmosphere (EA) Credit 4, and the Existing Building (EB) v2.0 – EA Credit 4, state a requirement for achieving one credit associated with Enhanced Refrigerant Management as follows "...a project can not install fire suppression systems that contain ozone-depleting substances (CFC's, HCFC's or Halons)".

As fire suppression systems are not directly addressed in the LEED criteria an additional avenue for obtaining further LEED credits is to apply under the Innovation and Design Process. Under this clause it is necessary to document and substantiate the innovation and design process used. By outlining the environmental properties of modern clean agents (zero ozone depletion potential, low to negligible global warming potential), the unique benefits of clean agents when compared to traditional water based systems (electrically non conductive) and the people safety of these agents (when used in accordance with US EPA guidelines and per NFPA 2001) a strong case can be made for an additional certification credit.

FIRE DETECTION TECHNOLOGY

Fire detection systems play an important role in green buildings. By detecting the fire quickly and accurately (i.e. by not sacrificing speed or causing false alarms) and providing early warning notification a fire detection system can limit the emissions of toxic products of combustion, and global warming gases produced by the fire itself. These environmental effects are often overlooked, but are undoubtedly present in all fire scenarios, and reducing the likelihood of fire is an important part of designing a green building.

Aspirating smoke detection systems which can detect the early stages of combustion, are one thousand times more sensitive than conventional smoke detectors, thus giving very early warning to the building occupants and owners of a potential fire. This early warning allows for emergency response well before a fire can take hold and cause serious damage. It is not uncommon for this type of system to detect smoldering cables, or overheating circuit boards. Early detection is ideal for both limiting damage and limiting downtime.

It should be noted that a complete fire protection system also typically includes spot smoke detectors (such as ionization and photoelectric types). These smoke detectors provide indication to signal the a fire control panel that the fire suppression system should be deployed. It is not recommended to discharge a fire suppression system solely from aspirated smoke detection systems, thus making spot detectors a necessary part of the overall green building fire protection system.

FIRE SUPPRESSION TECHNOLOGY ADVANCES – CLEAN AGENTS

From the mid 1960's Halon 1301 was the industry standard clean agent for protecting high value assets from the threat of fire. Halon 1301 had many benefits as a fire suppression agent; it was fast acting, safe for people, safe for assets and required minimal storage space. Halon 1301's major drawback is that it depletes atmospheric ozone. The Montreal Protocol, introduced in 1987, initiated the demise of Halon 1301. The installation of new Halon systems is now rare and in almost all cases uses reclaimed and recycled Halon 1301 agent, for a few select applications in aviation and the military as well as a small number of applications categorized as "essential use." Replacement of an existing Halon system can contribute to the "greening" of a building when using one of the newer, environmentally friendly agents discussed below.

In general the most commonly used fire suppression systems available today fall into two broad categories: clean agents or water mist. Clean agents include: Halocarbons, Fluorinated Ketone and Inert Gases. A table of the available alternatives is shown below and a discussion of the most commonly used systems follows.

FLUORINATED KETONE

The most recently developed agent is 3M™ Novec™ 1230 Fire Protection Fluid. This agent has the most favorable environmental profile of all of the chemical clean agents, with a Global Warming Potential of one (1) and Atmospheric Lifetime of only five (5) days. Increasingly Novec 1230 Fluid fire suppression systems are becoming the choice of the most environmentally conscious building owners.

HALOCARBONS

Halocarbon agents are similar in many respects, although each agent has some subtle differences. Halocarbons are active agents that extinguish fires by directly interacting with the fire itself. All of the Halocarbon agents are electrically non-conductive, most require some form of super-pressurization with nitrogen. Each of the Halocarbon systems has a typical discharge time of ten seconds, providing rapid discharge and consequently rapid extinguishment.

By far the most popular halocarbon agent is HFC-227ea (trademark FM-200). Due to its solid environmental profile of low global warming potential and zero ozone depletion potential FM-200 has been widely used in green buildings for over a decade. A testament to its environmental credentials is that the US EPA chose FM-200 to protect their National Computer Center (a Silver LEED facility) , built in Research Triangle Park, NC.

INERT GASES

In contrast to the previous agents, inert gases are

Category	NFPA 2001 reference	Other names	Advantages	Disadvantages
Fluorinated Ketone	FK-5-1-12	3M™ Novec™ 1230 Fire Protection Fluid	GWP = 1 Handling & transportation	Recharge costs Small HF production
Halocarbons	HFC-227ea	FM-200®	Product availability & approvals ADS Halon drop-in technology	Moderate recharge cost Small HF production
	HFC-23	FE-13™	Extreme cold temperature applications High ceiling efficiency	Moderate GWP Moderate storage space required High pressure system
	HFC-125	FE-25™	Low cost option (usage/lb efficiency)	Small HF production
Inert Gases	IG 55	Argonite®	Low enclosure integrity required Low agent cost for recharge Lengthy pipe runs	High pressure system Large storage space required Pressure venting required
	IG 541	Inergen®	Low enclosure integrity required Low agent cost for recharge Lengthy pipe runs	High pressure system Large storage space required Pressure venting required
Water mist	Water mist(*)	HI-Fog	Highly efficient against class B fires Low enclosure integrity required	Initial installation cost High pressure system

(*) Water mist systems are designed to NFPA 750

Is Your Data Center Experiencing Growing Pains?

Low-voltage PureWave UPS System

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PureWave UPS System Ratings

System Rating		Voltage
kVA	kW	
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2500 to 20 000	2000 to 16 000	4160 to 27 000

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The extraordinarily high efficiency of the S&C PureWave UPS System is in keeping with the goals of *The Green Grid*™, a consortium of information technology professionals and companies seeking to lower the overall power consumption of data centers and improve their efficiency. S&C supports these goals and is a member of this organization.

the green grid

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considered passive agents, in that they alter the atmosphere around the fire and do not directly interact with the fire itself. Inert gases are used to lower the oxygen content within an enclosure typically to 10-14%, where oxygen concentration below 12-14% will not sustain combustion. A number of different inert gas blends have been used in fire suppression, as shown in the table above. All of these inert gases are electrically non-conductive; they are stored as high pressure gases and have discharge times in the order of sixty seconds. Since oxygen levels are reduced, occupancy of the protected space post-discharge is typically restricted in comparison with Halocarbon extinguishants.

As inert gases both Argonite and Inergen have a zero global warming potential and have been used in green buildings for many years. The largest limitation on these systems is the storage space required due to the inability to store these inert gases as compressed liquids, leading to significantly larger space requirements than systems such as FM-200 and Novec 1230 Fluid. This can preclude these systems from many applications, however if storage space can be planned in advance these systems are viable options for green building owners.

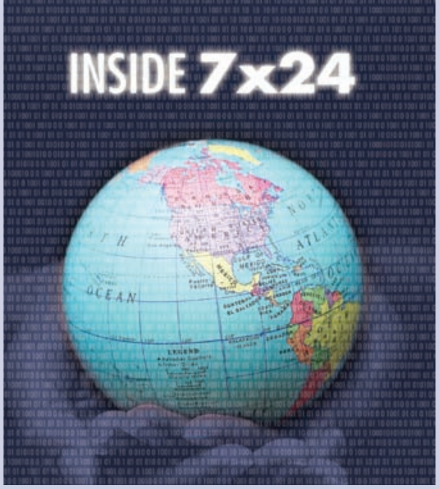
WATER MIST

Water mist systems are by definition green, using water as their suppression media, and having zero global warming or ozone depletion potential. The application of fine water drops, or mist, utilizes the fire extinguishing capabilities of water to its maximum, while conserving the water quantity used. Thus significantly less water can be used in a water mist system than in a traditional sprinkler system. The most popular water mist systems are typically high pressure so caution is required in their operation and use, however any risks can be mitigated by appropriate training and ongoing maintenance.

CONCLUSION

Green buildings have a many options when selecting fire protection systems. Careful consideration of the facility and the anticipated hazards will determine the hazards needing protection and codes and standards will help guide the system design and installation. Through advances in technology both fire detection and suppression systems can support and sustain the green philosophy in today's modern buildings. Further the selection of a clean agent or water mist system can contribute to LEED certification credits for building owners.

Kate Houghton is the Director of Marketing in Kidde Fire Systems. She can be reached at kate.houghton@kidde-fenwal.com.



2009 SPRING CONFERENCE HIGHLIGHTS

The Spring Conference themed ***"End-to-End Reliability: Managing Data Centers in Turbulent Times"*** will be held May 31 - June 3 at the Boca Raton Resort & Club in Boca Raton, Florida. The Spring conference will feature compelling keynotes, concurrent and tutorial sessions, sessions on the greening of data centers and managing in turbulent times, a spectacular vendor event, and more...

Stuart Varney, Business & Financial Journalist for Fox News will kick off the conference with a session entitled ***"Plain Talk – The Economy in the Age of Obama."*** In addition, a panel of recognized industry leaders from SUN, Vanguard, Deutsche Bank, Digital Realty Trust, Comcast and Microsoft moderated by Kevin Heslin of Mission Critical Magazine entitled "Managing Data Centers in Turbulent Times" will explore how to design and operate today's critical infrastructures without impacting operations or compromising efficiency while controlling costs. Michael Healey, Contributing Editor of Information Week will close the conference with a keynote entitled "Green IT in 2009 – The New Challenges of Responsibility, Accountability, and the Economy. In keeping with the theme, additional presentations on managing data centers in today's economy will be delivered with topics such as:

- Firefly – Data Center Evolution: The Shift from Operational to Transformational to Revenue Generating Data Centers
- eBay – Data Center Mixology: e-Bay's New Mega Center
- EMC – Thrive with Efficient IT
- EPA – Data Center Efficiency with ENERGY STAR: An update on EPA's Data Center Rating Initiative
- SUN – Data Center Re-Evolution: Change Happens
- IBM – Wanting It All – Best Costs with Reliability and Green

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For the complete Spring Conference program and registration information please visit 7x24exchange.org or call (646) 486-3818.

Mission critical industry leaders Bob Cassiliano, Chairman of 7x24 Exchange, and Ken Brill, Executive Director of the Uptime Institute at the 7x24 Exchange Fall Conference.

James Bradley, Best-Selling Author of Flags of Our Fathers *kicked off the 2008 Fall Conference with a session entitled "Doing the Impossible".*

For the complete Spring Conference program and registration information please visit 7x24exchange.org or call (646) 486-3818.

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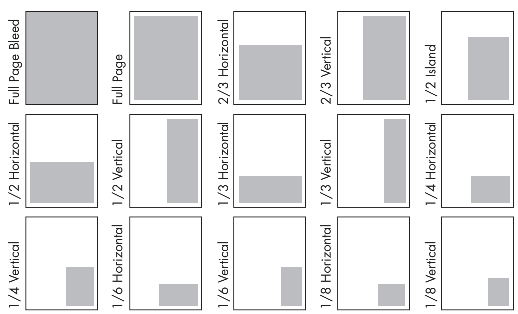

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