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Focus on data centers

Designing efficient and effective data centers and mission critical facilities is a top priority for consulting engineers. Read about engineers' work in data centers; manufacturers' solutions are featured online.

CSE: Please describe a recent project you've worked on.

Cyrus Gerami: I recently worked with a national collocation client on a 180,000-sq-ft Tier 2I collocation data center in Fairfax County, Va. It is a four-story building with an infrastructure cellar and eight co-location suites (N+1 MEP). The central chiller plant uses highly efficient magnetic oil-free compressors and evaporative condensers. Use of waterside and airside economizers is being closely evaluated. The facility power is backed up by eight 2.5 MW standby generators plus a ninth swing generator. In another project, for a national wireless phone company, we're working on a 21,000-sq-ft wireless company switch room expansion using a refrigerant cooled rear-door cooling system. At another wireless phone company, we are working on an $80 million expansion and renovation of an existing data center. This facility has an N+N redundancy capacity, which includes two separate utility power services and twice as many emergency power generators. The facility has 184,000 sq ft of building area with 70,000 sq ft of raised floor. Use of computer room air handler (CRAH) with airside economizer and ultrasonic evaporative cooling was the unique feature of HVAC system. Electrical infrastructure was the first of three major phases of this project. This required that the electrical service and all main switchgear be replaced or upgraded to handle the higher projected densities for the facility IT load as well as the projected building expansion. The phase one load was projected at 15 MW of power. This necessitated installation of new 34.5 kv medium voltage switchgear with double-ended boards with unit subs at each end and six 2.5 MW generators. Concurrent with phase one was the build-out and augments of three IT suites of 5,000 sq ft each to support existing load as well as projected future IT growth. All were designed or upgraded to support 200 W/sq ft IT load. Phase three included upgrading the existing chiller systems to meet the higher load demands created.

Kerr Johnstone: Our Industrial & Advanced Technology (I&AT) group recently completed a new build collocation data center for Digital Reality Trust with the end client being Terremark in the Netherlands. The I&AT office in Glasgow, Scotland, provided the skills and expertise covering architecture, mechanical, and electrical professional design services together with project management. The network access point (NAP) of Amsterdam will serve as Terremark's flagship facility located within the Amsterdam Airport Schiphol area, providing 25,000 sq ft of data center space featuring the latest in technological and engineering advancement. The facility is designed to meet Terremark's highest performance criteria, offering advanced cooling, power, redundancy, and sustainability features to maintain the availability of business-critical applications while reducing energy consumption.

Keith Lane: The Sabey Quincy Data Center in Quincy, Wash., is an exciting recent project that we were heavily involved in. A brief description of the electrical topology: The MSG consists of two single-wire ground return (SWGR) with a main-tie-tie-main. Each unit substation can be fed from either of the MSG boards. The transformer switch position can be selected between MSG 1 and MSG 2 for full concurrent maintainability. Additionally, there are spare conduits brought from the MSG to the unit substations for redundancy. The system has full N+1 redundancy. Floor-mounted

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static transfer switches allow for full concurrent maintainability without reducing dual-cord servers to one cord. Tier certification by the Uptime Institute was not pursued, but the data center is designed toward a Tier 3+ scenario.

James McEnteggart: We recently completed mechanical, electrical, and plumbing (MEP) commissioning of the two phases of a new data center in Sweden. This is a 370,000-sq-ft facility, which includes a 60,000-sq-ft white space designed to achieve U.S. Green Building Council LEED Gold. The design uses 100% airside economization with an evaporative cooling system and an electrical system with a 48 Vdc UPS system integrated with a 240 Vac server power supply. In winter, the hot air from the servers is even used to heat the office area. This mechanical solution also avoided the costs of buying, designing, and installing a conventional chiller system.

CH2M Hill's recent work on a Terremark data center in the Netherlands included advanced cooling, power, redundancy, and sustainability features to maintain the availability of business-critical applications while reducing energy consumption. Photo: CH2M Hill

CSE: How have the characteristics of mission critical facilities and data centers changed in recent years, and what should engineers expect to see in the near future?

Lane: Mission critical facility owners expect more with less. The engineer needs to stay abreast of the latest technologies and distribution scenarios to ensure the most reliability for the money. At the same time, energy efficiency as measured by both average and maximum power usage effectiveness (PUE) is critical. We are also seeing more failures of existing data center electrical duct banks. These failures are typically seen in data centers designed a decade or so ago that are now being used to their full potential. High load factors seen with new servers are heating the electrical duct banks to levels not anticipated. In most of the cases that we see, Neher-McGrath heating calculations were either not performed or not performed correctly, or the contractors did not install the duct banks with proper compaction.

Rener: There has been an increasing focus on facility costs, energy efficiency, and flexible/expandable designs. I believe we are approaching limits in what we can do on the facility side in terms of energy efficiency, commonly measured as PUE, and the focus is turning to the data equipment itself.

Menuet: Energy efficiency is increasing in importance, the environmental envelope has widened, and options for cooling delivery systems have multiplied. Data center HVAC systems are the low-hanging fruit now in the quest for improved energy performance of data centers, deservedly so. Systems and equipment have historically been targeted to maximize availability, and there is plenty of room for improvement. Next, we will see improved partnerships between engineered cooling solutions and server manufacturers. Data center environments can be improved if room cooling configurations are taken into account by the manufacturers. In addition, mechanical systems will be more closely coupled to end load. There is a large energy advantage to removing heat directly from the source with water, rather than moving it around in big clouds of air. Cold plate technology and direct water-cooled microprocessors will become more common.

Johnstone: A large and continuing focus for mission critical facilities is providing the infrastructure required to support the increased load and demand due to the increased processing power

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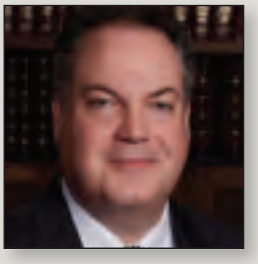

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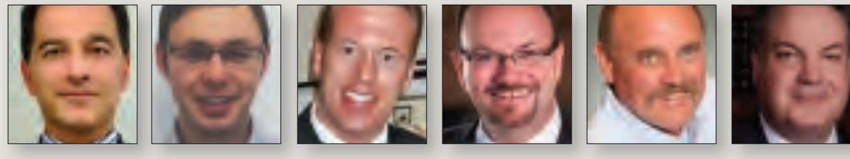


available in the data center racks. Clients want to provide resilience and capacity, but designers need to be cognizant of overdesign and overprovision at an early stage, so designs need to be able to adapt. This increased demand will continue the focus on design efficiency in the use of materials, plant, and space in addition to true operating costs.

We are seeing higher densities and high load factors in the new cloud-based data center.
—Keith Lane

McEnteggart: Twenty years ago, banks, telecom companies, and other major data center owners were primarily focused on ensuring reliability and maintaining high levels of availability, which required a lot of redundant mechanical and electrical systems at a high capital cost. As energy prices have increased, owners are taking a much broader view of the total cost of ownership—the total cost to build and operate a facility and provide IT capability—using new metrics such as "cost per megawatt."

Gerami: Changes include: Collocation/cloud computing, upward trend of W/sq ft or KW/rack seems to be flattening as more efficient servers are being introduced to market; energy conservation code's impact on data centers design and operation; and telecommunication facilities upgrading to be data centers—landline phone facilities providing wireless smartphone contents.

CSE: How have cloud data centers affected your work? What trends are you seeing?

Lane: We are seeing higher densities and high load factors in the new cloud-based data center. Loading of generators and the rating of the generator becomes more important, as well as the requirement for Neher-McGrath heating calculations for the underground electrical duct banks. Additionally, based on the type of application and the level of geo-redundancy, we are seeing varying levels of redundancy within a data center. Gone is the time where the entire data center was designed toward a certain tier level. Some applications may not require extremely high levels of reliability. Other applications may require a Tier 3 to Tier 4 topology. The client can save money during the installation and run at lower PUE levels for those applications requiring less reliability.

Menuet: The direct impact has been nominal based on our clients, which are typically brick-and-mortar companies, and the majority of our customers still want control over their data. We see companies creating business in the cloud but not taking business to the cloud—for now.

McEnteggart: With the development of cloud computing, there is a trend toward ensuring reliability and availability using multiple data centers in different geographic locations rather than one, highly robust data center with redundant mechanical and electrical systems. An owner can effectively build two Tier 2 data centers for far less than the cost of one Tier 4 data center—and when the Tier 2 facilities act as backup to one another, the result is a more reliable system than a single Tier 4. As commissioning agents, this means we may be testing and commissioning a greater number of data centers for a given owner, but spending less time at each because of the lower level of system complexity.

CSE: When designing integration monitoring and control systems, what factors do you consider?

Rener: The level of data and control the owner is seeking. Examples of data include the level of power quality information that is needed on at the mains, energy usage down to rack level, and temperature and humidity information. On the controls, we often have involved discussions on power shutoff (emergency power off, or EPO) systems.

Menuet: Controls design is a compromise between necessary complexity and making the system simple to operate, as well as providing access to information necessary to monitor the system. It's a balance between user flexibility and system integrity.

Johnstone: Key considerations in the

Features of the Sabey Quincy (Wash.) data center, engineered by staff from Lane Coburn & Assocs., include many aimed to enhance electrical reliability, including advanced generators and transformer switches. Photo: Lane Coburn & Assocs.

design and integration of monitoring and control systems are the resilience of the system and the fundamental actions of the system in a fail condition. Systems are designed to allow components to failsafe and work independently of central control and monitoring upon the loss of network capability. Another important aspect particularly in a co-hosting environment is where clients require Web-based monitoring to allow their external clients to review and audit the operation of the rented space and services to the space.

Gerami: Controls are prepackaged and tested by the equipment manufacturers. This minimizes equipment level failure and limits the levels of responsibilities. Integrate various systems and components into dashboards. Develop "what if?" scenarios to identify fail modes for better risk analysis. Interactive and intuitive user interface graphics can be set up to provide real-time data and trending. Consider PUE real-time calculations and built-in tools that will allow operators to adjust variables.

McEnteggart: As commissioning agent, I've seen many integrated MEP control systems that did not perform as designed during testing and commissioning. From my experience, two critical success factors are use of a third-party integrator for multi-vendor system integration and physical separation of the MEP and IT network infrastructures.

CSE: How have Energy Star, ASHRAE, The Green Grid, etc., affected your work on mission critical facilities and data centers? What are some positive/negative aspects of these guides?

Gerami: There is a need for more integration of efforts and publications. Codes rely on the research and recommendations from the industry. Sometimes the published data are in conflict or outdated.

Johnstone: ASHRAE TC 9.9 has opened opportunities to use a broader range of cooling solutions; however, these are not applicable for all projects due to client constraints and risk-averse industries (banking/ financial). As these cooling technologies become mainstream, solutions will focus on energy efficiency.

Menuet: The Green Grid led the way, developing the first accepted metric for data centers: PUE. ASHRAE is addressing critical environmental conditions and system configuration issues with manufacturers. One challenge presented by ASHRAE guidelines is that when initially developed (prior to TC 9.9), they were very commercial office building-centric, and it was difficult to apply them to data centers. The development of TC9.9 has created useful guidance and tools for mission critical facility designers.

CSE: Describe some recent electrical/power system challenges you encountered when designing a new building or retro-commissioning an existing building.

Rener: We recently faced a challenge in coordinating the ride-through time of rotary UPSs and the standby generators. The generators require a certain amount of time to ramp up and come to full load while the rotary UPSs have limited ride-through time.

McEnteggart: On a recent project, our client was expanding the UPS system to support new white space. The challenge was testing the new equipment without putting the ongoing data center operations at risk. Because we were involved during design, we were able to ensure that the system was configured to allow independent operation of the new equipment while allowing the existing UPS system to continue to support the critical space.

Johnstone: On a Terremark project, a considerable electrical systems challenge we encountered was where we converted an existing catering facility into a new data center. One of the main electrical systems challenges was achieving the adequate space required for the considerable amount of electrical equipment, which is essential in ensuring a reliable and high availability electrical system. We overcame these challenges by working extremely closely as a project and client team to develop an electrical system efficiently space planned ensuring all plant was compartmentalized but located in extremely close proximity to related plant, which increased efficiency while reducing installation cost.

> When using backup power systems such as UPSs, there has been a great focus on energy efficiency conversion technologies.
> *—Brian Rener*

CSE: How do you balance the need for reliable power with the desire for efficiency and sustainability?

Lane: Good engineers can provide a design that provides both reliable power and energy efficiency. Right-sizing equipment, understanding the client's reliability needs (they are not all the same), selecting the most efficient equipment, using higher voltages, and working closely with the mechanical engineer can ensure success.

McEnteggart: The catcher system is a good example of a design concept that attempts to balance reliability with efficiency. It allows high utilization of the installed infrastructure; however, it introduces the risk of fault propagation from the primary system to the redundant system. This can allow a fault in one part of the system to cascade through the redundant system and take down multiple parts of the facility. On paper, it is as reliable as some of the more conservative designs, but the owner has to decide if the potential efficiency of the catcher system is worth the risk to the system's reliability.

Rener: When using backup power systems such as UPSs, there has been a great focus on energy efficiency conversion technologies. There is a wider variety of topologies from UPS vendors to provide highly energy efficient designs. Coincidentally, higher power densities had resulted in the use of higher voltages such as 400 Vac and even 380 Vdc, which also results in less energy loss.

Johnstone: On a Terremark project, we implemented a static flywheel UPS system, which provided reliable backup power until the facility's standby diesel generators started and were available to take the facility's full load. The flywheel's autonomy was 15 seconds at full IT design load. While this appears insufficient time in terms of a UPS autonomy, it was proved during factory tests—and more importantly on-site during commissioning of the electrical systems—that we were able to have the generators online and supporting the full load of the facility in less than 10 seconds. This meant we didn't have a large quantity of batteries that are typically found in traditional data center designs. By removing these batteries we became considerably more efficient in terms of not just the space and the requirement to condition the rooms to tight environmental tolerances, but also the sustainable aspect of disposal/replacement of a large quantity of batteries over the facility lifespan was an added benefit.

CSE: What PUE goals are clients requesting, and what tactics are you using to accomplish this?

McEnteggart: Typical PUE requests range from 1.3 to 1.5. To achieve this, the design must incorporate into the building's mechanical and electrical infrastructure techniques, such as air-side economization and evaporative cooling, water cooling, new UPS systems with "energy saver" mode, and high-voltage power supply, where these are appropriate.

Rener: We are seeing requests for PUE less than 1.3 and sometimes much less. The key has been the ability to use "free cooling" depending on site location, using hot and cold aisle containment, and pushing the thermal limits for operating inlet temperatures of data equipment. The use of 400 Vac distribution is also allowing us to avoid additional transformers and the losses associated with stepping down to 120/208 V.

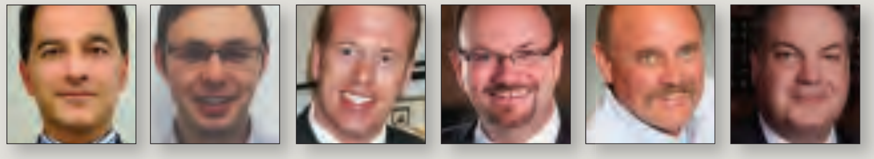
Lane: We see a lot of claims of extremely low PUE numbers in the industry. We must be careful to dig deeper and understand what these numbers represent: for example, best case scenario, calculations, average or peak real PUE numbers. The electrical infrastructure must be sized based on the peak worst-case PUE, but the cost of running the facility will be based on average PUE.

Johnstone: Clients are targeting very low PUEs—industry advertising indicates PUEs in the 1.1 to 1.2 levels. However, these are not achievable for every solution. In some aspects there is still an element of informing the client about the achievable solutions based upon their design criteria, location, and tier aspirations, and not all clients are educated in the implications of achieving very low PUEs. Adopting good design principles will typically achieve below 1.5 PUE on all but the most demanding projects.

CSE: What is your primary choice for standby, backup, and emergency power?

Rener: The old standard of a diesel generator is still commonplace. In many cases due to high power demands, the standby equipment is now specified at medium voltage (15 kV). However, we are getting requests for more "battery-less" continuous power systems to marry up to the generators. This commonly points to rotary UPS or in some cases generator rotary combination systems. There are interesting new developments , such as compressed air storage, fuel cells, and other new technologies.

McEnteggart: From an operational perspective, diesel generators are still my primary choice for emergency power. Some



owners are interested in microturbines, gas turbines, or cogeneration. While these may be economically attractive alternatives for data centers, an owner cannot rely on these systems to be there when they are needed—especially if they are burning natural gas. As we learned on the East Coast during Hurricane Sandy, natural gas utilities may shut down the flow for safety reasons. As far as I know, this did not impact any large commercial data centers, but in my mind, the benefit of natural-gas-fired emergency power isn't worth the risk.

Johnstone: We do not believe that there is a single primary choice on this subject as every project has its own challenges that can and do very often result in very different solution in terms of standby, backup, and emergency power. These challenges are influenced by clients' preference, geographical location, product support, space availability, and cost of ownership.

CSE: What unique fire suppression systems have you specified or designed in mission critical facilities and data centers?

Johnstone: For different clients we have used various suppression systems, and while Terremark employed a water mist system within its data center, we have used other methodologies. A project in Budapest (Hungary) employed a nitrogen-based system, which for code compliance required a "live" test for the local authorities. In addition we also have experience with a CO_2 suppression installation for generator containers, while an argonite gas suppression system was retrofitted into an existing live data center without any impact on its operation.

CSE: Energy efficiency and sustainability are often the No. 1 request from building owners during new building design. What is your experience in this area?

Johnstone: Energy efficiency is an increasingly important element for all clients, and PUE is a focus for all data center design. However, while we can be innovative in our approach to energy efficiency, this is sometimes compromised by the requirement to comply with conservative and more traditional design and approaches inherent within some client briefing and internal client design standards. Within all projects, we design elements of free cooling, and variable volume technology to drive down cooling production and distribution costs.

Lane: For mission critical facilities, the No. 1 priority is reliability. One outage can erase all the energy savings from a more efficient design. That being said, there are numerous strategies that can make a data center more efficient without reducing reliability. That is the secret sauce in the design.

Menuet: All data center end-users have increased their attention to energy efficiency, and in some cases have used the LEED program as a guide to building more efficient facilities. We continue to be challenged by the fact that mission critical buildings are heavy utility users, and the proportion of credits that address those issues in many green building programs is limited. The next generation of sustainable design guidelines specific to mission critical facilities must be heavily weighted toward electric and water usage.

CSE: What unique requirements do mission critical facility and data center HVAC systems have that you wouldn't encounter on other structures?

Rener: High power density, medium voltage distribution systems, need for specialized cooling and air floor containment, low impedance grounding, and multiple tiered generator and UPS systems are some of the requirements. However, we also design semiconductor cleanrooms, so we are used to encountering many of these issues regularly.

Gerami: Enormous power and cooling requirements that must be delivered with reliability, redundancy, and energy efficiency.

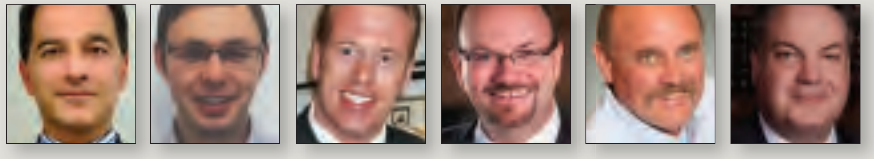
In my mind, one of the most interesting developments is related to the dramatic decrease in the cost of VFD in recent years.

—James McEnteggart

Menuet: Challenges include the 24/7 aspect of continuing operation; concurrent maintenance; fault tolerance; equipment redundancy; chemical treatment of large redundant piping systems; computer room air quality issues, particularly when using large amounts of outside air; and coordination of HVAC systems with end-user requirements, especially when server requirements are unknown. You have to try to anticipate future needs during design and accommodate a variety of future scenarios. We are also working in a lot of tight spaces, trying to design air delivery system that optimize the space available while delivering adequate cooling and loads. In response, we are using hot and cold aisle containment. The design must be flexible enough to allow users to choose from a variety of equipment but with a rigid enough structure to make sure the HVAC works.

McEnteggart: Mission critical facilities and data centers have a unique requirement for continuous operation during power outages. As data center power densities have climbed into the stratosphere above 150 to 200 W/sq ft, a power outage that shuts down the air handlers even for a minute will result in enough heat to shut down the computers. Today, many mission critical building owners require UPS systems on the air handlers so they can maintain a constant air temperature until the emergency generators start.

Johnstone: Selecting a provider with experience in operating a data center is critical as it helps demonstrate they have



the experience and knowledge of providing and ensuring high resilience availability, which is the major difference between normal commercial buildings and data centers and mission critical facilities. The increased levels of resilience and tier matrices criteria require larger space requirements and maintenance regimes than would be otherwise be found in a commercial environment.

CSE: What changes in fans, variable frequency drives (VFDs), and other related equipment have you experienced?

Johnstone: Working in an almost industrial application, noise can be a significant concern, but fan types have changed to being more efficient plug fans and fan selection is more influenced by reduced fan maintenance and assessing energy consumption. VFDs help improve the energy performance of the fan and are now seen as a standard requirement on all systems, helping reduce costs dramatically over the last 10 years.

Rener: I've seen the use of large fan arrays for air circulation and exhausting, chillers that are more robust and responsive to load fluctuations, and a variety of equipment dedicated to air side economization and increased energy efficiency.

McEnteggart: In my mind, one of the most interesting developments is related to the dramatic decrease in the cost of VFD in recent years. As a result, I'm seeing designs in which VFDs are being used in constant speed applications simply for the soft-start capability due to the low cost of the VFD versus the traditional starter. Many engineers have stopped specifying balancing valves on pumps; instead, they use VFDs to support balancing and flow adjustment of the pumps.

Menuet: There has been an increased application of electronically commutated motors (ECMs). VFD use for fan speed control is also more widely used and applied to traditional forward-curved fans to achieve energy savings through variable speed operation. We are seeing increased application of variable speed control to air delivery systems to reduce consumption.

CSE: Is water-based cooling becoming more prevalent in new facilities? What about outside air (free cooling)?

Gerami: Yes. Both are being used more and more.

Rener: There is a certain heat density where water cooling becomes preferable, if not required. Water or air side economization (free cooling) is becoming more and more a part of most facilities, depending on local climate and the temperature and humidity range the IT equipment will allow. Adiabatic (evaporative) cooling using nothing but ground water has been implemented in several of our projects.

Johnstone: In Europe, the majority of solutions will be derived from air-cooled equipment. The majority of this equipment will be free cooling in nature or additional free cooling circuits will be introduced as part of the cooling circuits. Where water-cooled chillers are introduced, this in normally via a dry cooling heat rejection cycle.

Menuet: Yes, we're seeing end users build in provisions to their systems for direct water cooling of IT equipment for servers. We are also seeing a drive toward direct evaporative cooling and outside air.

McEnteggart: Adoption of water cooling has been slow, with a notable exception being high-performance computing arrays. Outside air, or free cooling, is becoming commonplace in new designs; however, these systems need more space due to large ductwork requirements. The cost trade-off between the larger space requirements and energy savings should evaluated with an energy model before committing to this approach. cse

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