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review

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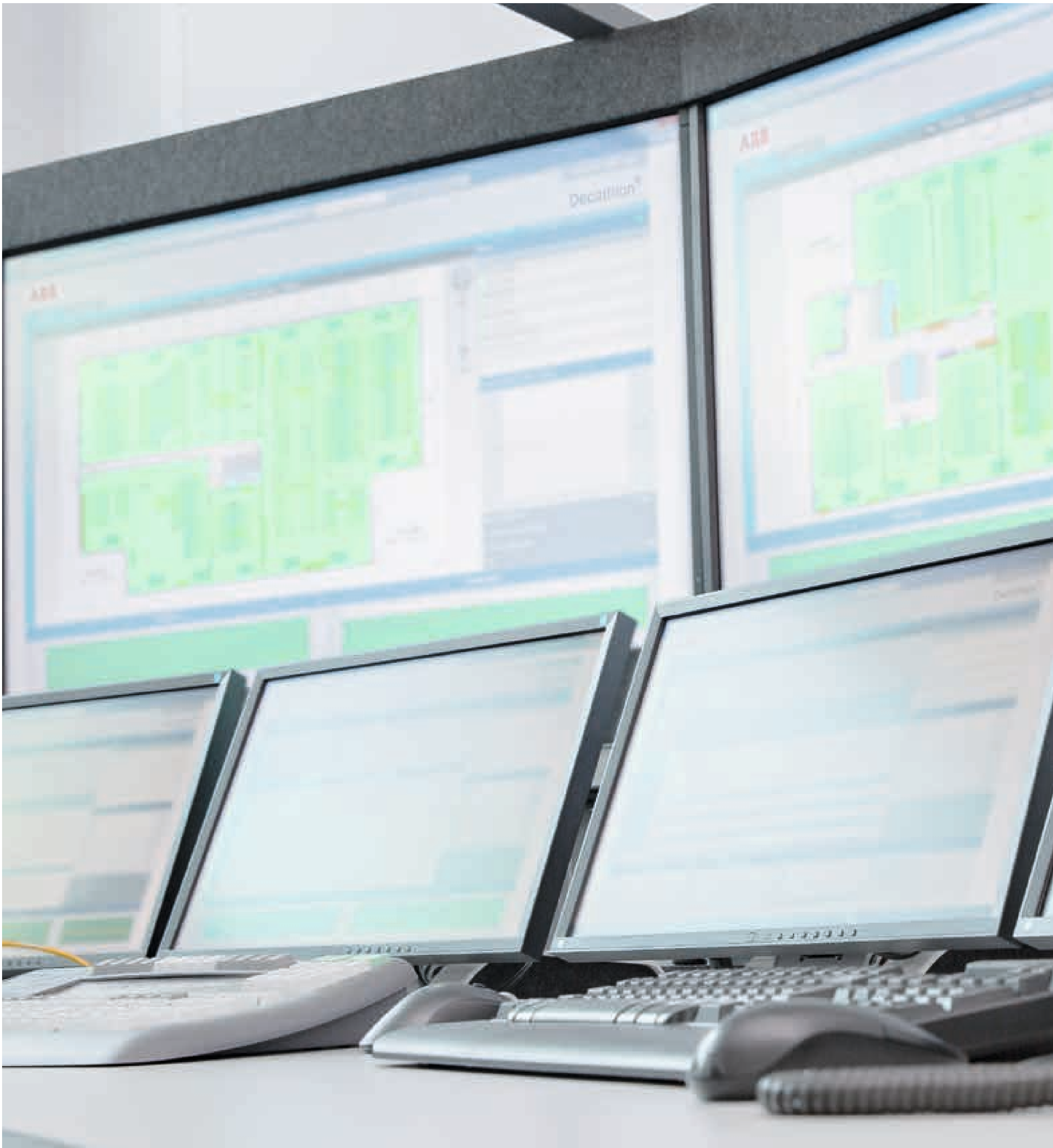
The corporate technical journal

Power and productivity
for a better world™



In 2012, ABB supplied the world's most powerful direct-current (DC) power distribution system at the greenDatacenter Zurich-West facility in Switzerland. This 1 MW installation demonstrates that DC systems are less complex than AC systems, making fewer power conversions, requiring less space, and reducing equipment, installation, real estate and maintenance costs. In early 2013, the facility earned the prestigious Watt d'Or award for the scale of the energy savings achieved. Later in the year, ABB installed its Decathlon® DCIM, an advanced data center infrastructure management system that ensures maximum reliability, energy efficiency and optimal utilization of all data center assets (see also page 16).

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Data centers and critical technologies

Claes Rytoft

Dear Reader,

You may be surprised to learn how deeply involved ABB is in the dynamic and continually expanding sector of data center technology – and has been from its very beginning.

Data centers began to develop in earnest around the time of the so-called dot-com bubble in the 1990s when demand for fast and continuous Internet connectivity began its steep growth, and in-house resources of individual companies could no longer keep pace. Large facilities called Internet data centers (IDCs) were created to handle increasingly large-scale computing. In his book "The Big Switch," Nicholas Carr describes seeing a data center for the first time in 2004. He observed that a data center was much like a power plant – a computing plant that would power the information age much as power plants had powered the industrial age.

While accurate, Carr's analogy seems so vastly understated today: The data center has become the most crucial IT asset for nearly any 21st century enterprise. The path of increasing digitalization is rendering the uninterrupted flow of data absolutely essential for day-to-day (even fraction-of-a-second to fraction-of-a-second) operations. The IT industry analyst 451 Research predicts that global data traffic will reach 11 zettabytes/month by 2017 (zetta means 10^{21}). Data centers are becoming ever larger, more complex and more costly to run. This edition of *ABB Review* looks at these trends, explores how data centers operate and – importantly – how their reliability can be maintained.

While the layperson may associate data centers foremost with arrays of servers processing information, the associated power supply and its control (including such functions as cooling) are equally vital. In fact, with the global power consumption of data centers rapidly approaching that of countries like Argentina or the Netherlands, the effective use and management of this energy (while upholding extremely high levels of reliability) is becoming a topic of ever-increasing societal relevance.

Building on its background in supplying mission-critical power and automation technologies, ABB has similarly become a player in the supply of key components and systems to the IT industry. While other suppliers are assembling data centers from components designed for commercial and office use, ABB offers inherently reliable, robustly designed and energy-efficient products and systems. The value of ABB's contribution to data centers is evident not only in the quality of individual products but also in the company's ability to develop and implement entire systems, covering both the power delivery chain as well as automated monitoring and control.

Beyond the articles related to data centers, this issue of *ABB Review* also looks at an electric bus that recharges in 15 s, automation on board a dredger and a robust wireless communications system for industry.

Enjoy your reading.

Claes Rytoft
Chief Technology Officer and
Group Senior Vice President
ABB Group


Decathlon
ABB

Data center defined

The infrastructure behind a digital world

MIETEK GLINKOWSKI – Today's mobile society means that people are consuming and creating data at unprecedented levels – the Internet, search engines, mobile apps, smart phones – all are omnipresent, yet their existence is basically taken for granted. The reality is that all of today's mobile gadgets, and more and more of all business enterprises, depend on the storage, networking and processing of digital data, nearly all of it via or inside a data center. Without question, data centers are the backbone and unsung heroes of the Internet boom, and have become a vital industry for organizations to run mission-critical applications. ABB provides a wide range of products, integrated solutions and expertise that ensure data centers operate safely, reliably and efficiently.

Title picture
In today's world of unprecedented amounts of data use and storage, ABB is helping organizations run mission critical applications.

1 Segments of the data center industry

There are a variety of distinct industry segments in which data centers are needed.

Colocation/hosting
Many small- and medium-size businesses do not want or cannot afford their own IT infrastructure such as data centers and so they outsource their IT needs to colocation companies. These companies provide IT services, from web hosting, to enterprise IT hosting, to other businesses. This segment of the data center market is clearly focused on revenues from IT; for them the data centers are the primary business offering.

Financials
Banks and other financial institutions such as the New York Stock Exchange (NYSE), NASDAQ, Tokyo Stock Exchange (TSE), etc. need data centers and their high availability to perform financial transactions but data centers per se are not their source of income.

Telecom
From landline digital services to the mobile and smartphone, telecom providers play a major role in the data center industry. Today, virtually all phone services are digital and many of them use VoIP, utilizing the connectivity of the Internet. Major players such as NTT, AT&T, T-Mobile, all own, build and operate data centers.

IT services
Companies such as Google, Amazon, eBay, Facebook and others debuted with the Internet boom approximately 15 years ago. Although these companies rely on data centers as their primary assets, their revenue stream varies from advertising to online shopping. They are innovative in their way of building data centers, providing services and serving customers.

Government
In 1999 the US Federal government operated 432 data centers; in 2013 this number had risen to about 7,000*. This includes everything from the Internal Revenue Service to the Department of Defense and Social Security Administration. For government agencies data centers are a cost.

Healthcare
This segment is expected to grow rapidly with the emerging trend of digitalization of patient records and all medical data from private doctor's visits to hospitalization and major surgeries. For the healthcare industry data centers are a cost.

Corporations, retail, manufacturing, utilities
This includes a large group of private and publicly traded companies in a variety of industries such as oil and gas plastics, retail store chains, and power, gas and water utilities. Although many small and midsize corporations would choose collocation services the larger companies own and operate their dedicated data centers. For example, in Singapore, BP operates its Most of the World (MoW) Mega Data Centre, one of four mega data centers from which BP runs its global IT operations.

Cloud computing is not considered a segment, but rather a service, within the database industry. It is a means of distributing IT applications over a number of physical servers and even physical data centers. There is no longer a direct relationship between an application and a physical device or even physical data center. A good example of this is Apple's iTunes application where data – eg, music, videos, movies – is distributed over a combination of servers and separate Apple data centers. This distribution is dynamic, ie, it depends on resources, availability of IT (as well as power, cooling and several other factors), Internet traffic, etc.

Footnote
* Government Accountability Office of the US Government, 2013, www.gao.gov

Current state-of-the-art data centers are highly specialized industrial facilities, full of intricate and interrelated equipment and systems with particular mission-critical needs → 1. Some may be small buildings of 200 m², others the size of 15 soccer fields (about 140,000 m²). Some require 500 kW of power, others 100 MW.

The field is expanding at a tremendous rate. For example, globally, the number of IT racks in 2012 reached 7.7 million – an increase of 15 percent compared to 2011[1]. Estimated growth for data centers this year in the United States was 25 percent with some countries, for instance Turkey, reporting a 60 percent growth. The expansion of the corporate data center industry was well captured in a report by Digital Realty.[2] → 2 shows the most important performance factors and features fueling the expansion of the industry. Energy efficiency and security were viewed as extremely important, whereas consolidation, connectivity and redundancy were rated as very important to somewhat important. ABB provides cost-effective solutions to meet the needs of today's data centers.

Data centers consume large quantities of electrical energy. Current estimates are that up to 2 percent of global energy is consumed by data center enterprises.[3] With the global installed electricity capacity of about 5,000 GW[4] this means data centers consume about 120 GW, almost twice as much as the electricity capacity of Mexico, and more than the countries of Spain or Italy.

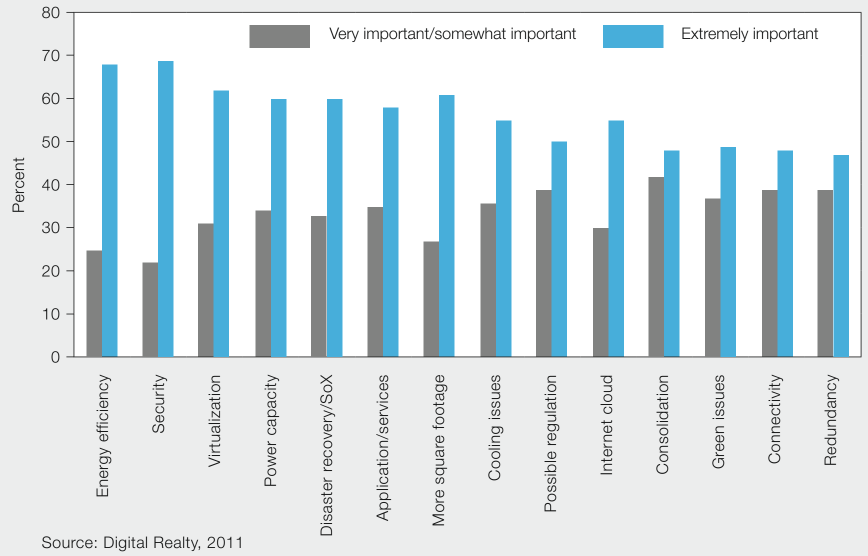
A large variety of software, databases, operating systems and clouds run in data centers.

What is a data center?

Data centers can be defined as three side-by-side infrastructures – IT, power and cooling → 3. The three infrastructures have to be perfectly compatible, matched, and optimized to provide seamless operation of the mission-critical facility → 4.

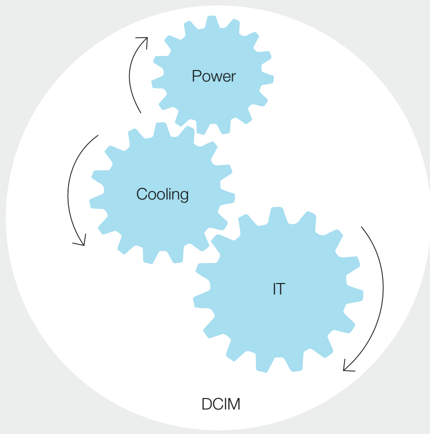
The IT infrastructure contains primarily the IT equipment with its associated software. The equipment is typically grouped into three categories: servers, network switches and storage (memory). Each group has its unique function; however in many cases servers

2 Where do professionals see priorities in data center expansion?



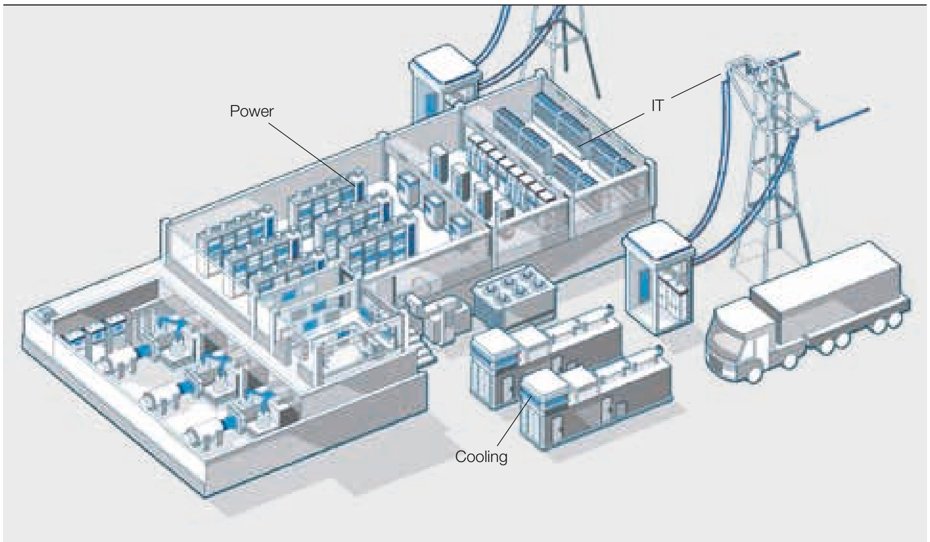
Source: Digital Realty, 2011

4 Data center infrastructure



Data center infrastructure includes the interplay of IT, power and cooling with DCIM.

3 Physical layout of a generic data center



contain storage. This infrastructure is where the main functions of the data centers are implemented and the IT services are delivered. A large variety of software, virtualization, databases, web hosting, operating systems, and clouds run in data centers.

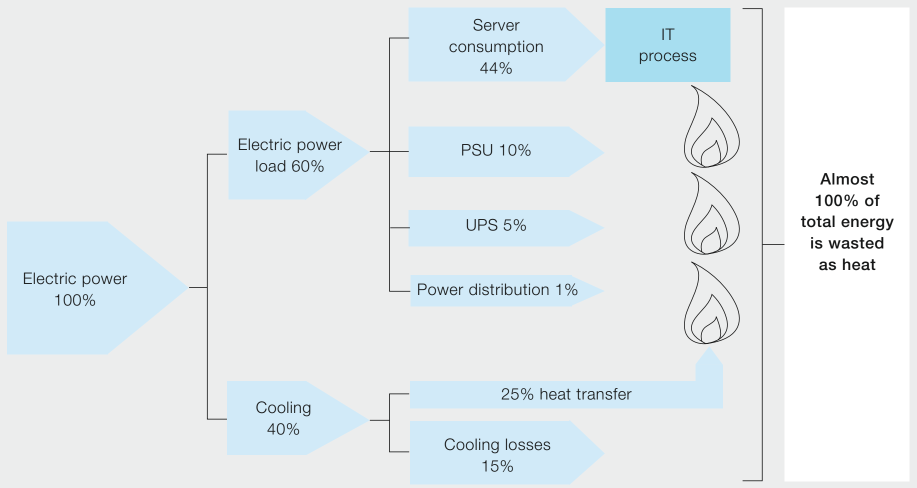
Power and cooling are the two infrastructures necessary to operate the IT equipment. Power is primarily in the form of grid electricity (although there are some exceptions, such as fuel cells). Power is delivered to the IT equipment via complex topologies of transformers, switchgear, gensets (rotating engine generator sets), uninterruptible power supplies (UPSs), busways and automatic transfer switches. The raw power from the utility is transformed, converted, conditioned and distributed to the servers in the IT racks.

IT equipment generates a lot of heat. The power infrastructure accounts for 60 percent and cooling accounts for 40 percent of the energy consumed in a generic data center ➔ 5. The power usage effectiveness (PUE) factor is equal to PUE = 100/55 = 1.82, which is better than the industry average of 1.9. The power infrastructure can be broken down into four components, eventually leading to the IT processes (IT equipment) consuming about 44 percent of the total. Nearly all of the electricity flowing through the power infrastructure and used in cooling is lost as heat.

Footnotes

1 Data Center Dynamics Converged – Media Pack 2012
2 What is Driving the US Market? 2011, Digital Realty Trust
3 The estimates vary from 1.1% to 2.5 %; see multiple sources: http://www.analyticspress.com/data centers.html, www.greenpeace.org, www.forbes.com
4 Data as of 2010 EIA.gov

5 Simplified energy balance for a generic data center



The electric energy is consumed 60 percent by the power infrastructure and 40 percent by cooling.

The power usage effectiveness (PUE) factor would be equal to PUE=100/55=1.82*), which is better than the industry average. UPS losses and all cooling power are counted as overhead power.

The power infrastructure can be broken down into four components, eventually leading to the IT processes (IT equipment) consuming about 44 percent.

Footnote

* The alert reader may be confused that the P_{load} figure is 55 rather than 60. The difference of 5 percent is accounted for by the the UPS losses shown.

This heat has to be removed to assure that the operating temperatures of the equipment stay within the specifications and that the environment around the equipment can be accessed by personnel. Data centers employ very sophisticated and diverse cooling systems to control this environment, including liquid cooling, air cooling, immerse cooling, hot-aisle containment, cold-aisle containment, computer room air conditioners (CRACs) and computer room air handler (CRAH) units. Cooling is the primary component of the energy consumption responsible for the overhead power, ie, PUE factors above 1.0 → 6.

Another component of the infrastructure, data center infrastructure management (DCIM), is becoming increasingly more important. DCIM is a platform to collect, control, integrate, monitor and manage all the systems of the data center. Ensuring that the temperature sensors of the cooling CRAC units are set properly to match the temperature requirements that servers read on their own motherboards is not a trivial task, nor is making sure that the power distributed to the racks of the IT equipment loads the individual feeders in a uniform fashion and does not overload individual cables and circuit breakers. Keeping track of where the IT equipment is located, what purpose it serves, when it needs to be replaced, or who owns it (in the case of a colocation company) is also necessary. All of these functions and more can be handled by a DCIM platform consisting often of both hardware and software to collect the data (eg, temperature, voltage, current, air flow, alarms), process it, display it and enable an operator to make informed decisions. DCIM is referred to as the glue that holds all the components of a data center together – an all-encompassing umbrella for the data center business.

6 Performance indicators

Power usage effectiveness (PUE) is the most common key performance indicator (KPI) for data centers today. It is defined as

$$PUE = \frac{P_{Total}}{P_{IT\ Load}}$$

where P_{Total} is the total power consumed by the data center, $P_{IT\ Load}$ is the power consumed by the IT load. By definition PUE is always greater than 1.0; everything above 1.0 is overhead power consumed by other non-IT loads, such as cooling, lighting, security systems.

The average PUE reported by the environmental protection agency (EPA) in the United States in 2007 was 1.9 (90 percent overhead power consumed). In 2012 Digital Realty reported that the average PUE for non-IT companies was even worse, approximately equal to 2.9.

However there is more to the energy consumption than PUE. For example, if a data center owner improves the energy consumption of the IT load – ie, replacing older servers with the newer technology – and keeps the same cooling system the PUE will actually increase since the denominator of the PUE equation decreases.

In some cases this can be a disincentive to modernize facilities. In other cases in an effort to improve the PUE factor, data centers switch to more water-intensive cooling and therefore consume more water. This is why a new set of KPIs have been introduced, including water usage effectiveness (WUE). Carbon usage effectiveness (CUE) is a data center measurement that takes the total CO_2 and carbon equivalent emissions produced as a result of the data center energy used and divides it by the energy of the IT equipment housed in the data center; the value is in $kgCO_2e/kWh$.

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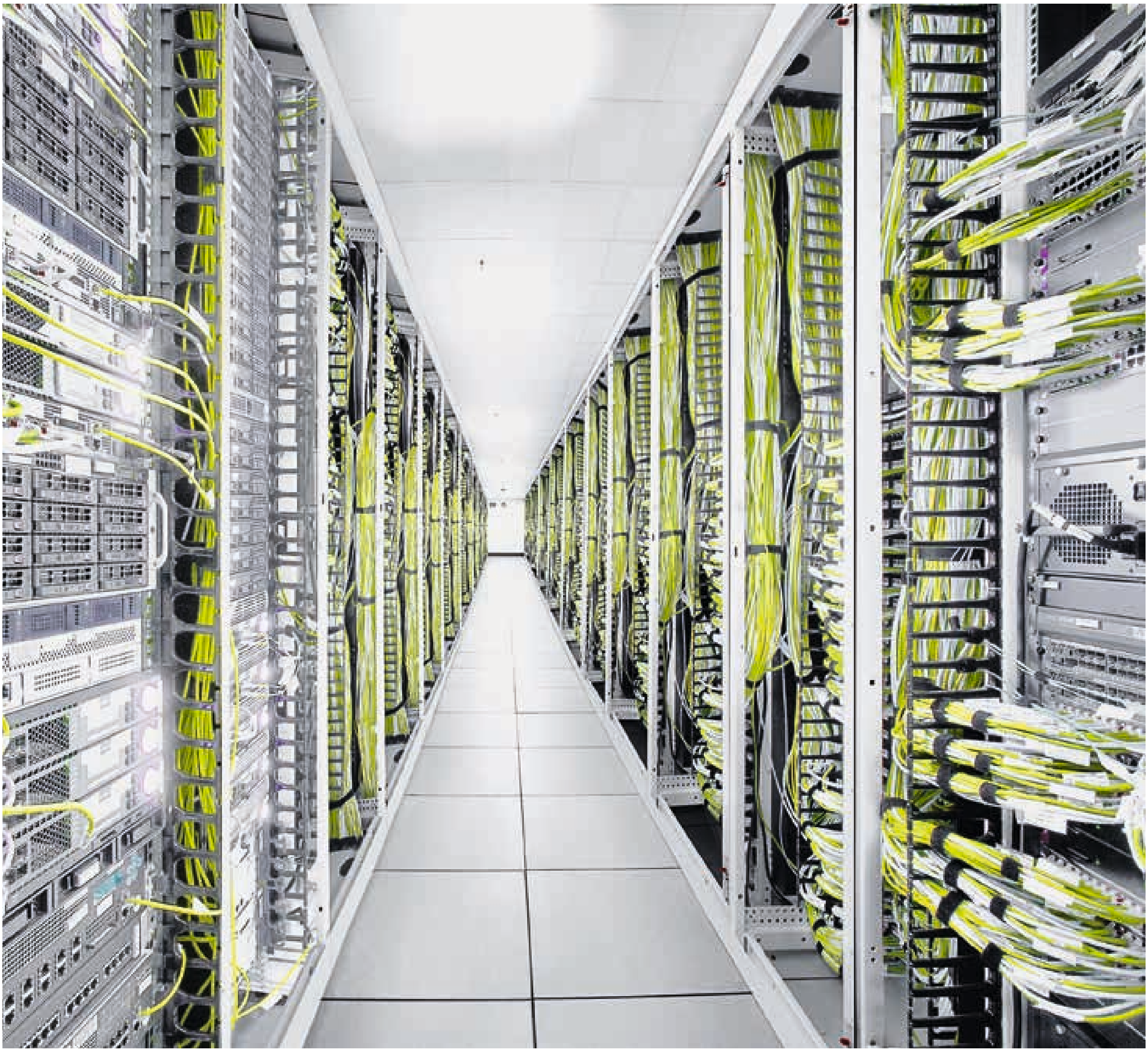
Further reading
www.abb.com/datacenters



Designed for uptime

Defining data center availability via a tier classification system

MIETEK GLINKOWSKI – All systems can fail – this is a simple fact that every industry must deal with. The paramount concern for the data center industry is the unbroken continuity of systems operations. Industry analysts estimate that a one-hour outage in a data center costs on average $350,000. And the cost is expected to only go up as more and more business enterprises depend on the storage, networking and processing of digital data, nearly all of it through or inside a data center. Since loss of service for a data center is so costly, even if only for an extremely short time, availability is still the most critical driver for data centers design, operation and maintenance.

The paramount concern for the data center industry is the unbroken continuity of a systems operation.

1 Reliability and availability

Reliability and availability are often misinterpreted and confused with the quality of a system or a product. Reliability is defined as a function of time:

$R(t) = e^{-\lambda t}$

where $R(t)$ is reliability, t is time, and $\lambda = Tf/Tp$ is a failure rate. Tf is the total number of failed occurrences during the total period of Tp. The longer the system is operating the lower the reliability. The parameter λ is a reciprocal of MTBF (mean time between failures). Mean time to repair (MTTR), which is the time needed to repair a failed system or device, is another important parameter. Used in combination, MTBF and MTTR determine the inherent availability (Ai) of a system or device:

$Ai = MTBF/(MFTBF + MTTR).$

If one expands the concept of availability to include the scheduled maintenance downtime the availability changes to the operational availability, Ao.

Reliability and availability are not fixed numbers. They are both functions of specific components of the system as well as the system topology, which determines how critical these components are to the mission critical function of the data center. Therefore, the reliability has to be evaluated at different points of the system where power is to be delivered to the IT load.

As mentioned, reliability and availability are not the same as quality. Quality refers to the condition of the new equipment when delivered to the customer – ie "out of the box." Reliability and therefore availability is measured over a period of time. This, besides quality, includes the effects of aging and stress level of the equipment within the system.

Increased reliability can be accomplished by redundancy (of equipment and delivery paths). However, the more equipment the greater the likelihood for one or more of the components to fail. For any system design there is a balance between the level of redundancy and associated complexity and reliability gains. Good system designs need to get the most out of the equipment, utilize their full potential and provide a sufficient level of redundancy and back up for reliable energy supply.

Availability of the data center refers to meeting the uptime expectations of the users. The current high availability of data centers has been achieved mostly through redundancy in design, equipment (both IT equipment and power devices), electricity delivery paths and software ➔ 1. Several classification systems exist in the industry to define data center availability. Rapidly changing technologies, desire to differentiate among themselves, environmental awareness and foremost cost pressures often dictate designs that either fall in between different tier structures or even seek more radical departures. The tier structure from the Uptime Institute, though not always followed, is considered an important industry guideline and thus is the classification referenced in this article. The Uptime Institute defines a four-tier system, where each level describes the availability as a guideline for designing data center infrastructure ➔ 2. The higher the tier, the greater the availability.

The lowest cost and the lowest performance data center, Tier I, has a target availability of 99.671 percent, which translates to 28.8 hours of annual IT downtime. The highest level data center design, Tier IV, has a target of 99.995 percent availability, or 24 minutes of annual IT downtime. The different tier designs are also capable of accommodating different power load densities, from 200 W/m^2) to 1,500 W/m^2. For power engineers it is important to realize that the higher the tier the higher the utility voltage supplied to the facility. This is predominantly related to the fact that the availability of power within a power system is generally increasing from low-voltage (LV) area distribution to medium-voltage (MV) distribution to high-voltage (HV) transmission systems. The closer one is to the infinite bus of a large power system the less the likelihood of a disturbance or blackout.

Tier I

This architecture is the simplest and therefore offers the lowest availability and lowest IT load power density. This design concept is called N, reflecting the fact that "n" IT loads need "n" sets of UPS units and gensets. ➔ 3 identifies the basic components of a data center, as described below.

Utility source

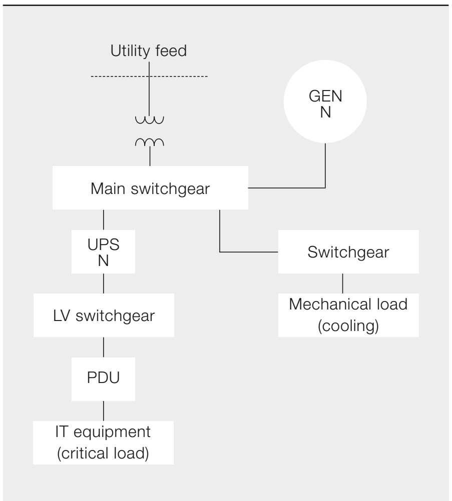
The utility source component in a Tier I classification feeds an input transformer stepping down from MV to LV.

Title picture
What sort of designs do data centers follow in order to meet the high demands for availability?

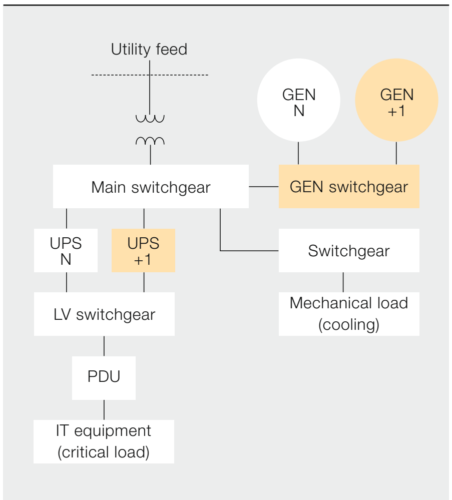
2 Tier similarities and differences

Number of delivery paths	Tier I Only 1	Tier II Only 1	Tier III 1 active 1 passive	Tier IV 2 active
Redundant components	N	N +1	N +1	2 (N +1) or S + S
Utility voltage	208, 480	208, 480	12-15kV	12-15kV
Annual IT downtime due to site	28.8 hours	22.0 hours	1.6 hours	0.4 hours
Site availability	99.671%	99.749%	99.982%	99.995%

3 Tier I design N



4 Tier II design (N+1)



The current high availability of data centers has been achieved mostly through redundancy in design, equipment, electricity delivery paths and software.

Genset

A genset is an emergency power generator, typically with a diesel engine, that provides a long-term power backup in the event of a utility outage. Long-term is defined by the amount of fuel stored in the tank and can vary from 24 to 72 hours. Having a high-priority fuel delivery contract can extend the time. The generator is in the form of a synchronous machine with power ratings of few hundred kW to 2 to 3 MW.

Automatic transfer switching

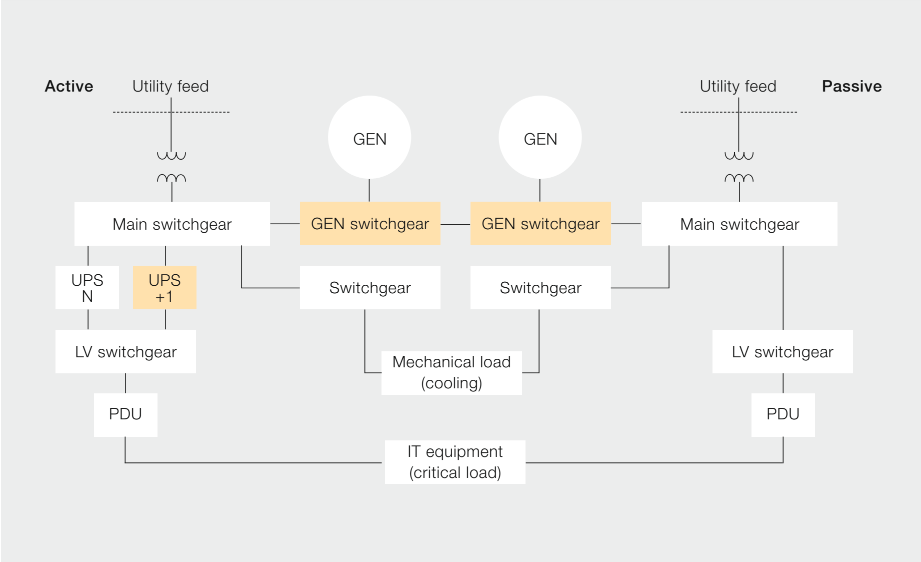
Using a specialized automatic transfer switchgear (ATS) with control and protection logic allows for a seamless switch from the source between the utility and the genset under a number of different conditions. Most of the time the switch from the utility to the generator is open-before-close – ie, when the utility power is lost the utility breaker is open and the genset is closed only after the genset has started properly, reached the desired rpm and excitation, and is synchronized. The starting of the genset can take a few seconds. With multiple gensets this time can increase to up to a minute.

Uninterruptible power supplies

There are primarily three types of uninterruptible power supply (UPS) technologies – standby, line interactive and double conversion. By far the most popular is double conversion, where all the power flowing through the UPS is rectified from AC to DC, inverted back to AC and therefore fully conditioned and cleaned from all utility-side disturbances, transients, voltage sags and swells, and other power quality (PQ) effects. The DC bus in the middle is also connected to the battery bank, which, in the event of power loss, provides short-term power. The switch between the utility AC power and the internal battery power is seamless and instantaneous. Short-term power is determined by the size of the battery bank and typically varies from 2 to 3 min to 7 to 10 min.

The addition of the passive delivery path significantly raises the cost of the entire system and also complicates the control, coordination and maintenance.

5 Tier III active-passive design; no UPS in the passive path



Switchgear

A variety of switchgear is needed in data centers to distribute the power to the many different rows of IT equipment (critical loads) as well as cooling equipment (pumps, fans, valves, compressors, etc.) and other auxiliary loads. The circuit breakers in the switchgear also provide protection against faults and other abnormal conditions. In the Tier I facility all of the switchgear is low voltage (less than ~1 kV).

Power distribution unit

Power distribution units (PDUs) are comprised of circuit breakers, metering units and, in North America, LV transformers, to further distribute the power to the IT racks as well as provide protection and measure the power (voltage and current) to the individual loads.

Power supply units

Power supply units (PSUs) are part of the IT equipment. Similar to the power supply of a desktop computer these units transform the 220 V or 110 V input power to the DC voltage distributed to the various IT equipment: servers, network and storage systems. The most popular PSUs are transformer-less switched mode power supply (SMPS). Due to the redundancy of the power distribution for Tier III and IV more and more PSUs are now provided with dual AC inputs and can function from either of the two.

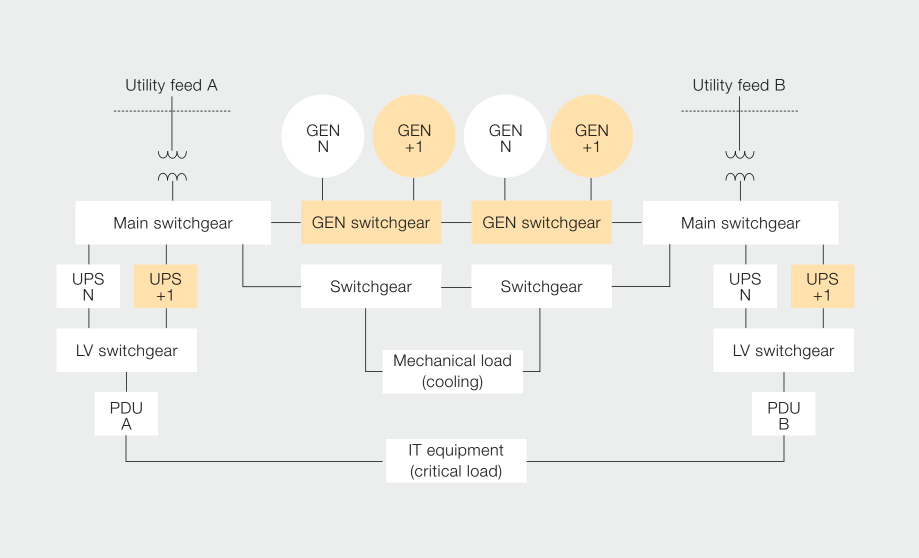
Tier II

This design is known as N+1 → 4. The primary difference between a Tier I and Tier II classification is the presence of an additional genset and UPS. This provides some degree of device redundancy of the most critical components of the system for short-term and long-term backup. All other components of the system are basically the same. Even with this redundancy there are still several different single points of failures in the path to deliver power to the IT load.

Tier III

Tier III is referred to as an active-passive system → 5. In a Tier III classification the power delivery path has to be doubled. Besides the redundant critical components there has to be a second path parallel to the critical IT load in case the primary path has failed. This second path could be passive, ie, used only in case of emergency. A Tier III classification also requires a second utility connection. The addition of the passive delivery path significantly raises the cost of the entire system and also complicates the control, coordination, maintenance, etc. There is also an additional switchgear and motor control center (MCC), which should allow the full operation of the data center from the passive path. The IT equipment can now take full advantage of the dual supply paths and therefore utilize dual PSUs for each server, for example. As a result the number of single points of failure is significantly reduced. However, the passive delivery path does not require UPS so during the emergency conditions the system is vulnerable to utility conditions, therefore potentially exposed to utility power quality issues or even power outages.

6 Tier IV design 2N+1; two simultaneously active paths



For any system design there is a balance between the level of redundancy and associated complexity and reliability gains.

Tier IV

Referred to as a 2N+1 system, the Tier IV classification is also considered the Cadillac of data center design ➔ 6. A relatively small number of data centers in the world are certified as Tier IV designs. They are fully redundant, complete dual systems running actively in parallel. By virtue of the redundancy the rating of each path has to be 100 percent of the load and therefore the maximum utilization of the two paths under normal operating conditions is at maximum 50 percent. In addition, some Tier IV designs will have N+1 of UPSs and gensets in each path, further increasing the complexity and cost but at the same time gaining the valuable fraction of a percent (0.01 percent to be exact) for availability. The target for Tier IV availability is to allow a maximum of 24 min per year of the annual site-caused end-user downtime (representing one failure every five years).

Tier IV designs are fully redundant, complete dual systems running actively in parellel.

Changes to come

Tier structure availability and downtime are not the only factors to consider. Impact of the interruptions on the operation of the mission critical facility can vary. For example, during one year, 10 short power interruptions at the server power supply lasting 50 ms each will have a much more detrimental impact on the operation of the servers than one longer interruption of 500 ms during the same period of time. Although both will result in the same annual availability (total of 0.5 s of lost power) the first one will cause the servers to reboot and possibly lose some data 10 times during the year; the second one will result in only one reboot a year.

Highly skilled engineering resources are needed to design, implement, and optimize the entire data center ecosystem for their availability and reliability. The traditional way of thinking about availability and reliability is changing rapidly. Increased system voltages, more sophisticated switching schemes, wider operating regimes for IT equipment, and foremost the advent of failure-resilient software and cloud computing introduce new dimensions to data center reliability. So, stay tuned.

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DC for efficiency

Low voltage DC power infrastructure in data centers

ANDRÉ SCHÄRER – Looking at all data centers worldwide, around 80 million MWh of energy are consumed each year, corresponding to about 2 percent of global CO_2 emissions. Before long, these values will be equivalent to the electrical consumption of Argentina or the Netherlands. With the addition of more than 5.75 million new servers worldwide annually, global carbon emissions from data centers will quadruple by 2020 – if the electricity mix does not fundamentally change and no measures are taken to increase energy efficiency. The thirst for power of a single medium-sized data center corresponds to that of approximately 25,000 private households in the United States (or almost twice as many in Europe). What can be done to make data centers more frugal energetically? ABB recognizes DC as an important tool in achieving this goal. DC offers several advantages, most notably lower losses by eliminating conversion and transformation steps in the power delivery chain. Losses between infeed and server can be reduced by 10 percent.

With DC, there are two less conversion steps in total.

The call for energy efficiency and for the comprehensive use of renewable energies is becoming louder and louder → 1. One important solution being promoted by ABB is the use of DC in data centers.

Direct current technology

The struggle between the proponents of AC (Nicola Tesla and George Westinghouse) and the advocate of DC (Thomas A. Edison) toward the end of the 19th century, also known as the "War of Currents," was finally won by AC. This system has dominated the transmission and distribution of electricity for more than 100 years.

So that means DC is dead? Far from it. In today's digital age, more and more devices are operated with DC – consumer electronics, industrial information technology, communication technologies and electrical vehicles, to name just a few. At the other end of the energy supply chain are photovoltaic systems and fuel cells (and some wind parks) that generate DC. In transmission too, there is a notable exception facing AC's predominance: high-voltage direct current (HVDC) provides large transmission capacity at low losses over long distances. ABB has played, and continues to play, a leading role as supplier and developer of the technology over its almost 60 year history.

With the growing role of DC in the fields of generation, transmission, storage and consumption, more and more electricity takes the form of DC at least once somewhere along its supply chain. Some conversion steps are necessary, but in some cases, the voltage and frequency levels used are justified by historical reasons only, and yet the associated conversion steps cause avoidable energy losses. Supported by advances in power electronics, ABB is reconsidering the incontestability of AC transmission and seeking to advance DC into fields where it can deliver energy savings.

World's most powerful direct current data center

Data centers are particularly suited for a DC supply. The reason is that there are a large number of identical, or at

Title picture
In 2012, ABB supplied the world's most powerful DC power distribution system, installed at the greenDatacenter Zurich-West facility in Switzerland.

This pilot project is a one-time solution specifically developed, installed and started up in record time for ABB's customer, Green Datacenter AG.

1 The road to efficiency

There are various approaches to making data centers more ecological; DC (direct current) technology is not the only tool in the arsenal. Other approaches include the location and design of the data center, technical advances in server technologies and cooling, better utilization and operational philosophies.

It is important to recognize that optimization restricted to individual components will lead to a less-than-optimal overall system. The key to success lies in considering the overall system including the interaction between the owners/operators of data centers and their hardware suppliers.

least similar, consumers (servers, network components, storage, etc.) thus limiting the multitude of voltage levels needing to be provided.

In 2011, Green Datacenter AG, the operator of the data center business for the Internet provider green.ch, decided to operate a 1,100 m² extension (of a 3,300 m² data center) in Zurich-West → title picture using DC technology and chose ABB as its partner.

This article explores the concept of DC distribution supplied specifically for this data center. This is a customer- and project-specific solution and does not in this form represent a standard product.

Technical solution

To demonstrate the efficiency gains on a large scale, it was decided to design the direct current supply system with a capacity of almost 1 MW → 3. A few smaller and similar systems are already in use around the world. They are however used primarily for research and development purposes.

With regard to the choice of DC voltage, an open-circuit voltage of 400 V was selected. On the one hand, it is necessary to keep the voltage as high as possible to minimize losses and the amount of copper needed. On the other hand, staff safety and equipment compatibility were taken into consideration (there are also indications that 380 V could develop into a standard in DC supply and distribution: Committees such as the IEC, NEMA and Emerge Alliance[1] have already addressed this topic).

Proven and industry-tested ABB technology was selected for the entire DC supply chain to ensure high reliability and availability. While the central rectifier unit was developed specifically for this project, its core contains the latest modular power electronics known from a multitude of other applications.

From grid to chip

The redundant infeed by the local utility uses 16 kV (medium voltage) from two independent substations.

This infeed, together with the emergency power of a diesel generator, is first fed to a gas-insulated medium-voltage switchgear of type ABB ZX0. An ABB Tanomat-type control system automatically ensures that the switches are set to the appropriate positions for the operating mode (normal operation, emergency power operation, test operation, backfeed to utility).

Rectification

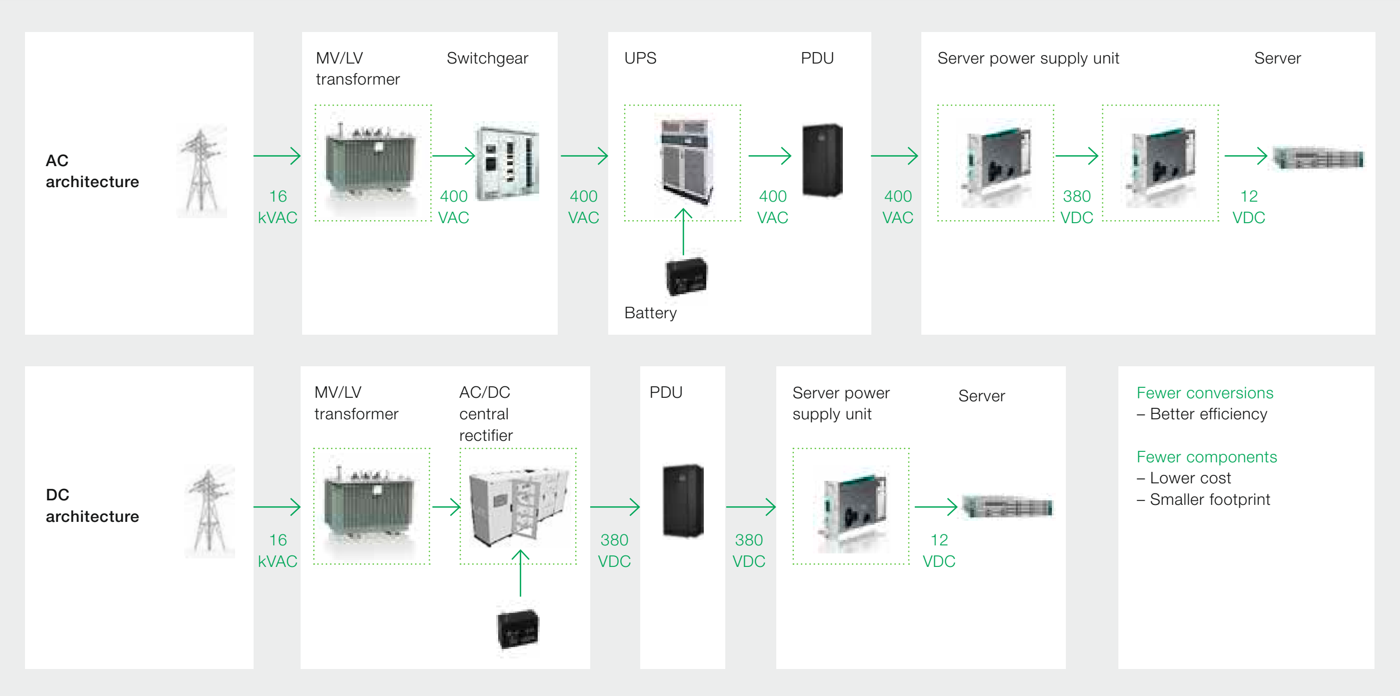
The output of the medium-voltage switchgear connects directly to the central rectifier unit. Within this unit, there is first a medium-voltage switch disconnector, followed by a highly efficient ABB 1,100 kVA three-winding dry-type transformer that converts the 16 kV to low voltage. Two parallel, thyristor-based, 6-pulse ABB DCS800-type rectifier modules then carry out the actual rectification – this step is performed once for the energy supply of the servers (main supply) and once for charging the batteries (these guarantee an autonomy of around 10 min at full load).

On the output side, the rectifier modules are connected in series. They thus enable a center tap, which can be grounded. The resultant three-conductor system provides L+ (+200 V), M and

Footnote

1 An open industry association leading the rapid adoption of safe DC power distribution in commercial buildings through the development of EMerge Alliance standards.

2 A DC supply for data centers involves fewer components and lower losses than AC



L– (–200 V), whereas the consumers are connected between L+ and L–.

The subsequent ABB MNS® low-voltage switchgear has two functions: On the one hand it serves as an interface to the batteries. On the other, it distributes

Proven and industry-tested ABB technology was selected for the entire DC supply chain to ensure high reliability and availability.

the energy to the MNS *i*S PDU (power distribution units), which are directly adjacent to the IT rooms and constitute a type of sub-distribution unit.

The MNS switchgear is designed for an operating voltage of 400 V DC and can convey a maximum constant current of 3,000 A. To ensure the safety of people and equipment in normal operation and in the event of a short circuit, the switchgear was also rigorously tested and certified by an independent laboratory – a maximum rated short-circuit withstand of 65 kA was certified, taking into account the particular conditions of this project (contribution of batteries to short circuit, etc.).

MNS *i*S power distribution units

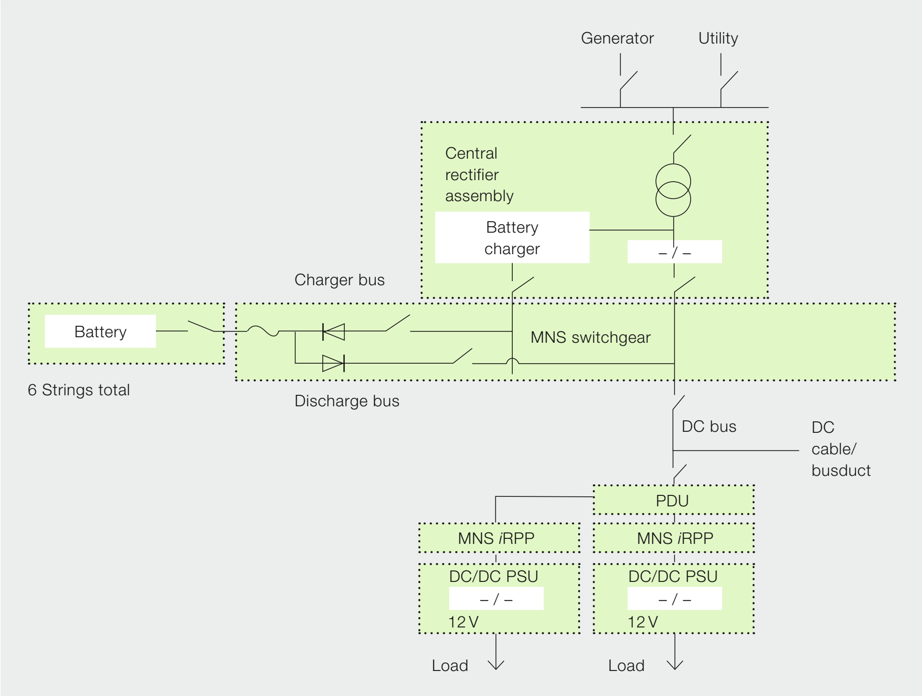
Two redundant MNS *i*S 400 V DC PDUs distribute the energy within the IT rooms and ultimately feed the servers. Depending on customer requirements, the newly launched ABB intelligent remote power panels MNS *i*RPP may additionally be used for this task, allowing more precise distribution. The MNS *i*S PDUs are based on the same low-voltage switchgear system (MNS) as the main distribution described above and have the same performance data, except that their rated current is 1,600 A (each).

Each output contains a high-precision measurement based on the shunt measuring principle. This not only makes individual energy measurement possible, but also enables predictive maintenance to be carried out, for example by measuring and recording the temperature in each conductor (L+ and L–) in real time. If the superordinate control system detects an abnormal state or negative trend, proactive intervention can be triggered therefore preventing a dangerous operating condition or malfunction.

Rigorous tests were performed to ensure the safety of people and equipment in both normal operation and in the event of a short circuit.

The discussions about the advantages of DC supply in data centers are often reduced to energy efficiency, but DC has many other advantages.

3 DC power supply for greenDatacenter



Server
The energy supply chain concludes with a rack containing various industry standard servers. A setup with one HP X1800 G2 network storage system, four HP ProLiant DL385 G7 servers, one blade system c3000 with three HP BL465c G7 CTO blades and one HP 5500-24G DC EI switch is used for demonstration purposes, with ABB running some applications to make use of the capacity.

There is a widespread yet erroneous view that IT hardware supplied with DC power differs from that supplied with AC.

There is a widespread yet erroneous view that IT hardware supplied with DC power differs from that supplied with AC. This is not so: The server is identical. The only difference is in the power supply unit (PSU). For DC, the unit is simplified (eg, omission of the rectifier). This has a positive effect on energy efficiency (an improvement of 3 percent and more as compared with a state-of-the-art AC PSU according to information from Power-One). Apart from the connection, there are no visible differences on the exterior (identical form factor).

System comparison
Comparison of the circuit topology implemented in this project against conventional AC (as also used at greenDatacenter), shows that with DC, there are two less conversion steps in total → 2. First, there is no traditional uninterruptable power supply (UPS) with rectifier and inverter. The rectification on the input of the server power supply unit is also omitted.

An AC data center for North America (fulfilling the ANSI standard) would have an additional transformer within the PDU to transform 480 / 277 V to 208 / 120 V – primarily for reasons of personal safety. In this case, the DC solution also has one transformation less.

Results
The energy efficiency of the power infeed through to the server (including the server power supply unit) can be improved by up to 10 percent when using DC compared with AC (depending on load). This is thanks to the smaller number of conversions and additional effects.

4 Advantages of new DC solution (to be launched in 2015)

– Active front-end AC/DC power conversion for minimal harmonic distortion
– Stable, regulated 380 VDC output with low ripple enables use of so-called narrow-band power supply units with highest efficiencies
– Superior rectifier efficiency over wide power range
– System cost significantly lower than state-of-the-art AC UPS system
– Smallest footprint and ease of access
– Truly integrated and modular platform, scalable in increments
– Microgrid enabled (ease of integration of batteries and alternative power sources without paralleling / synchronizing controls)
– Connection of AC legacy equipment
– Short-circuit-proof design
– Type-tested assembly

With the growing role of DC in the fields of generation, transmission, storage and consumption, more and more electricity takes the form of DC at least once somewhere along its supply chain.

Beyond this, the cooling needs in the IT room are decreased, which further reduces the energy required.

The discussions about the advantages of DC supply in data centers are often reduced to energy efficiency. DC's further advantages are only rarely mentioned. In this project, the following results could be achieved based on comparison measurements and real data:
– 10 percent improvement in energy efficiency (not counting the reduced need for cooling in the IT room).
– 15 percent lower investment costs related to the electrical components for the data center power supply.
– 25 percent less space required for the electrical components for the data center power supply.

Using fewer components also increases reliability and decreases the likelihood of human error.

The costs for installation, operation and maintenance also dropped thanks to simpler architecture and less equipment. The savings in installation costs amount to around 20 percent. This value is based on the experiences gathered in the project. Qualified statements on operating and maintenance costs cannot be made at this time.

A balanced, facts-based evaluation of DC and AC systems should take account of all factors, from planning and construction costs to operating and maintenance costs.

New generation

As mentioned above, this pilot project is a one-time solution specifically developed, installed and started up in record time for ABB's customer, Green Datacenter AG.

Presently ABB is developing a new DC data center solution that will further revolutionize the power supply architecture. The standard product will be launched on the market at the latest in 2015 and will boast the advantages laid out in ➔ 4.

Use of direct current and DC microgrid

DC is not the be-all and end-all for data centers. There are applications for which alternating current is more suitable. For optimum results, data centers must be considered in their entirety and planned in an integrated manner – from the grid infeed through to the server. In smaller data centers, savings may not be high enough in absolute terms to justify DC.

DC technology should preferably be used in new and large data centers. Its advantages diminish when it comes to renovations and small extensions to existing AC facilities.

However, the technology sees an additional boost when the data center is considered a DC microgrid – ie, it shifts from being a pure consumer (energy as an expense) to a generator (energy as a source for revenue) through "on-site generation." In this scenario, energy can flow in both directions. As numerous power conversions are eliminated, interconnection and compatibility for all on-site equipment is simplified. This can include on-site alternative energy sources (photovoltaics, wind, fuel cell, etc.), energy storage (eg, batteries) and consumers in the data center.

The idea of the data center as a microgrid is not a long-term vision – there are already initiatives and projects being pursued in this area.

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Backing up performance

ABB emergency power systems for data centers

MANFRED FAHR, RALPH SCHMIDHAUSER, JOHN RABER – Data centers are one of the least visible but most crucial parts of our modern infrastructure. The data they contain – bank details, medical histories, company data, pension records, tax returns, social media treasures (Facebook receives over 300 million new photos each day) and a plethora of other data – are, to different degrees, important to modern life. So reliant has society become on data centers that 100 percent uptime is now often an essential aspect of their operation. Despite all the precautions taken during the design and operation of data centers, situations can arise in which external power is totally lost for a significant period. Such blackouts result in data loss, nonavailability of essential services, risk to hardware and, potentially, financial losses of millions of dollars. For these reasons, highly dependable emergency power systems are increasingly mission-critical for the data center industry.

1 ABB gensets provide reliable backup power for data centers.

External threats to the power grid are difficult, or impossible, to control. Every year, storms and adverse weather conditions – for example, the recent superstorm Sandy in the United States – cause major power interruptions and stretch many emergency power systems beyond the limits of their capabilities. Construction-related incidents are another major cause of utility outages. Even without such events, utilities have to cope with power grids that are aging, increasingly decentralized and unpredictable. For a data center, therefore, a highly dependable emergency power system is a must.

Quality is paramount

Most data centers employ uninterruptable power supplies (UPSs) combined with diesel generator sets ("gensets") to safeguard against power interruptions or total loss. However, design and installation of gensets and emergency power control systems are often oversimplified and only poorly executed. This results in internal and "homemade" threats which are underestimated or even overlooked altogether. Critically, nonstandardized control systems and nonmatching or low-quality system components can introduce a single point of failure, thus increasing the risk of malfunction exactly when reliable power is needed most. Inferior installation practices can be costly too: One global Internet-based supplier was recently fined over half-a-million dollars for installing and repeatedly running diesel generators without obtaining the required standard environmental permits on a site in the state of Virginia, in the United States [1]. Poorly installed gensets are generally becoming a matter of concern.

In short, the performance, functionality and reliability of any emergency power system are highly dependent on, and determined by, the capabilities of the control system, the quality of all system components and the professionalism with which the system installation is carried out. Further, when developing world-class emergency power system concepts, all needs and benefits must be considered, not just the technical features → 1.

Scalability

Scalability is absolutely essential when designing modern backup power systems: Control and power systems have to grow seamlessly with increasing energy demand and adapt to changing customer needs and priorities. This has to be achieved without compromising quality or reliability, or introducing the need for system downtime.

Data center business cases often allow for expansion in several stages over time. A modern emergency power system has to be designed to provide full functionality from the initial operation levels right up to the final data center expansion stage. This requires thorough design of the supply concept, communication structure, control systems and building infrastructure. Standardized components with upstream and downstream compatibility and long-term availability allow for changes and extensions over a period of many years without the need to replace entire systems.

> At the heart of the ABB emergency power concept lies the programmable logic controller (PLC).

ABB system concepts are designed to allow for step-by-step extensions or changes without the need for system downtime and they accommodate independent testing of new stages without

Title picture
Data centers that aim for 100 percent uptime need a highly reliable diesel generator backup for the eventuality that the external power fails for a length of time. Just what are the characteristics of such an emergency backup system?

2 ABB control cabinets lie at the heart of the emergency power concept.

The performance, functionality and reliability of any emergency power system are highly dependent on the capabilities of the control system, component quality and the professionalism with which the system installation is carried out.

risk to the ongoing data center operation.

New criticality paradigms

Power criticality concepts and philosophies vary widely between industries and, in many cases, are unique to individual customers. Further, consumer groups can no longer be simply categorized according to whether they are merely UPS-supported or require emergency power or are supplied by the grid only. Rather, it is now essential to distinguish between consumers who can tolerate medium-length, short or no power interruptions. This changes the emergency power system concept, and selection and sizing of system components. Reliability can be further increased by reducing or removing less-critical consumers while providing power to essential servers only.

Controlling emergency power

ABB's emergency power activities include entirely new installations and modernizations of complete control systems that manage both emergency power groups and main distribution systems. At the heart of the ABB emergency power concept lies the programmable logic controller (PLC) → 2–4. The task of the PLC is to control the diesel engines and generators belonging to the emergency power groups and communicate with other control systems, individual consumers, UPSs, switchgear and the process control systems. The performance and reliability of a power supply system is highly dependent on, and, more importantly, limited by, the quality and capability of the control system and its components.

The PLC is a vital part of any critical power concept and represents a single point of failure – a failure that could have potentially catastrophic consequences. To mitigate this risk, ABB control systems are based on standardized components and offer compatibility with all other relevant ABB products. This allows conceptual changes, functionality upgrades and capacity expansions to be made at any time without interruptions, and without system availability and reliability being compromised.

Reliability and availability

ABB designs and supplies fully integrated emergency and backup power products and complete turnkey systems. Having one port of call for planning, engineering and installation of the complete system, including auxiliaries, allows for seamless integration, easy future expansion, simplified service and maintenance, while reducing the number of interfaces and thus increasing reliability. Bundling electrical system components such as low-voltage and medium-voltage switchgear, transformers and control systems with auxiliaries like fuel systems, exhaust systems, ventilation and cooling under one contract offers peace of mind for supply, integration, commissioning, maintenance and service.

High-quality standardized products also significantly reduce intervention time during maintenance or in the event of failure – components can be changed quickly and easily, service is simplified and some modules can even be hot-swapped.

3 Control cabinets can be easily modified and extended to accommodate data center expansion.

For a data center, a highly dependable emergency power system is a must.

Advanced technology

ABB is able to design emergency power concepts based on a range of technologies. A highly capable and scalable control system allows for the use of technologies such as diesel rotary uninterruptable power systems (DRUPSs) or even the integration of compressed-air power storage solutions.

Financial flexibility can be nearly as important as technical specifications. For instance, leasing and full-service models allow for accurate operational expense planning and maintain the highest level of reliability.

The most modern data center power technologies are based on direct current (DC). One of the top information and communications technology (ICT) service providers in Switzerland, green.ch, has chosen ABB to design and install an advanced, DC power distribution system in a new state-of-the-art data center (see also pages 16–21 of this edition of *ABB Review*). DC technology trims power conversion losses and is 10 to 20 percent more energy efficient than traditional alternating current (AC) technology when used for electrical distribution in data centers. DC systems are also less complex and require less space – reducing equipment, installation, real estate and maintenance costs. This can result in savings of up to 30 percent on the total facility costs. The green.ch data center uses ABB emergency power gensets ➔ 5.

The advanced AC500 PLC at the heart of the ABB Master control system provides an interface to ABB's data center infrastructure management (DCIM) system, Decathlon. Integrated fiber-optic communication rings enable the emergency

High-quality standardized products also significantly reduce intervention time during maintenance or in the event of failure – components can be changed quickly and easily, service is simplified and some modules can even be hot-swapped.

power controller to continuously communicate with upstream and downstream systems and components. Customers have the ability to monitor, analyze and control emergency power systems locally, and to increase supply security and optimize operations remotely, as required.

Remote monitoring and notification services have been developed to relay critical information to mobile devices including mobile phones. This allows an immediate response to threats and facilitates the planning of preventative measures to ensure that 100 percent availability is not compromised. Furthermore, remote access ability allows utility operators to access and purchase additional power during peak periods.

High-quality diesel engines

ABB utilizes only high-quality diesel engines from well-regarded original equipment manufacturers (OEMs). This enables ABB to meet and exceed the most stringent environmental requirements. Diesel exhaust systems can be designed to further reduce emissions and noise pollution.

ABB gensets comply with the stringent structural integrity obligations laid out by the International Building Code (IBC). The IBC is a broad collection of structural building requirements that help prevent injury and damage from earthquakes and other such phenomena. The IBC and other building codes are now written so that, in the event of a catastrophe, mission-critical systems will be able to withstand the same forces the building housing them can. A unit that complies with IBC seismic standards will have been certified through seismic analysis and tri-axial shake table testing.

4 Control cabinet interior

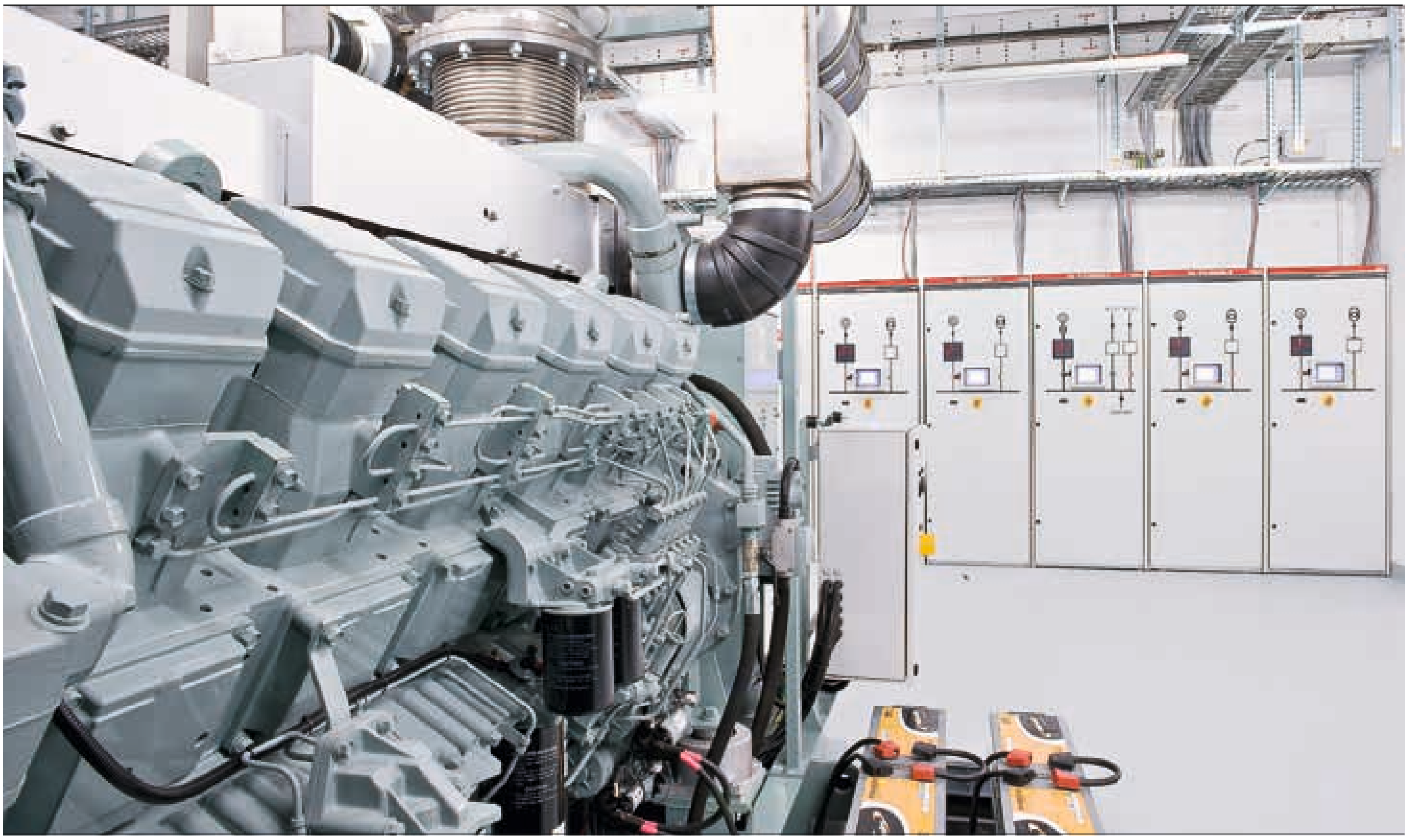
The IBC has been widely adopted in North America and ABB has already implemented many of its standards into its products.

All ABB industrial gaseous liquid-cooled (IGLC) and industrial diesel liquid-cooled (IDLC) stationary gensets meet the IBC wind resistance requirements. These requirements vary depending on exposure category and occupancy category – for example, a life-critical building such as a hospital requires a higher safety factor than a manufacturing plant or mall. Mathematical modeling of various scenarios and the stresses inherent in those scenarios has been performed on the gensets to determine their ability to withstand the wind under different situations.

ABB generators also comply with the Underwriters Laboratory (UL) UL 2200 standard for safety.

UL 2200 is the most widely adopted safety certification in the United States. If the genset operates at 600 V or less and is intended for installation and use in ordinary locations in accordance with the National Electrical Code NFPA-70, it can be designed to meet UL 2200 standard. This means that the unit has gone

5 Genset and master control cabinets (in the background) as supplied to green.ch. A redundant fiber-optic bus system is included.



Scalability is absolutely essential when designing modern backup power systems.

through rigorous testing to ensure it has a longer uptime, meets higher safety standards and will be less likely to fail than an equivalent noncertified unit.

Business models

Data center emergency power systems are significant investments so delivery and financial flexibility can be nearly as important as technical specifications. For instance, leasing and full-service models allow for accurate operational expense planning and the avoidance of unexpected costs, while maintaining the highest level of reliability. Other financial models accommodate upgrades, extensions and new technology platforms. Rental models avoid large capital expenditure, aid swift project execution, leave flexibility for future growth and provide clear and easy control of finances.

Technical and financial concepts also cater for interim solutions: Additional demand can easily be met with the addition of temporary power units and containerized systems can comfortably bridge the gap during extension phases without the need of risky and costly shutdowns and compromised availability.

As data centers increase in number and size, the emergency power systems that support them will grow in sophistication and capability. ABB will continue to develop this technology to ensure that data centers continue to conform to regulations and that its customers can continue to operate with 100 percent uptime.

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Reference

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Power guarantee

Uninterruptible power supply for data centers

JUHA LANTTA – The articles in this issue of *ABB Review* underline just how much modern society depends on data centers. It is of critical importance that there is zero downtime in data center operations, so a continuous supply of clean power must be guaranteed. The key component in ensuring this is the uninterruptible power supply (UPS). Because reliability is so crucial, it has been made a cornerstone of the ABB UPS design philosophy. In addition, as data centers are major consumers of electrical power, the high energy efficiency of ABB UPS systems brings a welcome reduction in the power bills landing on the doormat. Although data centers vary in their power protection needs, the combination of required availability and reasonable costs of ownership (initial investment and running costs) need not necessarily entail compromises if the appropriate insight is employed in optimizing the solution for each case.

Title picture
Disruptions in the power flowing to a data center can happen at any time and can jeopardize the integrity of the continuous operation of the data center. The problem can be avoided by choosing the correct UPS type and configuration. Shown here is the ABB Conceptpower DPA 500 UPS.

Power disturbances come in many guises: On top of total power outages and blackouts, the voltage may sag or swell over short periods; it may also do so over longer periods – so-called brownouts or overvoltages; there can be electrical noise on the line, or frequency variation; or harmonics may appear in the voltage.

A UPS remediates all of these

A UPS will condition incoming power ➔ 1. Spikes, swells, sags, noise and harmonics will all be eliminated. In the case of total power failure, power will be supplied from batteries or other energy storage systems. A backup generator will kick in for longer power outages. This ensures that data center operation is available around the clock and that no data corruption or loss will occur.

A UPS will condition incoming power. Spikes, swells, sags, noise and harmonics will all be eliminated.

Applications in data centers

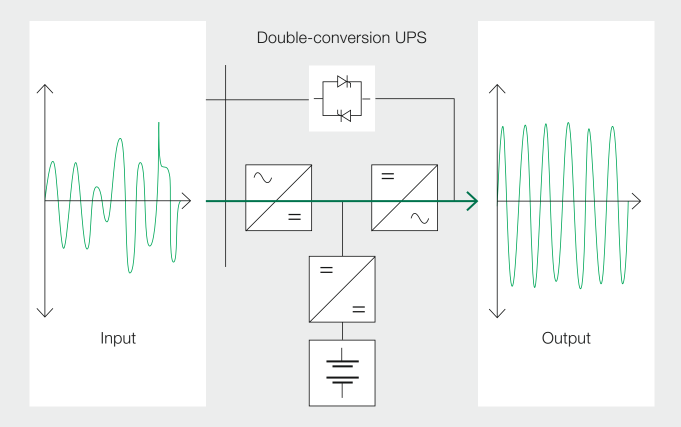
In a data center, the principal mission of the UPS is to protect the servers. The UPS can be located centrally or beside each row of server racks ("end of row" placement). The former topology is appropriate, in most cases, for large data centers and the latter is usually found in smaller data centers.

Servers are not the only elements of a data center that require UPS protection: Auxiliary devices and systems that manage cooling and safety, often called "mechanical loads," are also critical for the smooth operation of the data center and ABB provides reliable backup power solutions for these, too.

Data center designs and ratings

The detailed design of a data center depends on its size, power density and criticality. The power scheme is part of data center site's infrastructure and the Uptime Institute's Tier ratings (I–IV) give guidelines and help in understanding the levels of power protection that may be applicable ➔ 2:

1 Power disturbances



2 Characteristics of 4 tiers of the power infrastructure

	Tier I	Tier II	Tier III	Tier IV
Number of delivery path	Only 1	Only 1	1 active 1 passive	2 active
Redundancy	N	N+1	N+1	S+S or 2 (N+1)
Concurrently maintainable	No	No	Yes	Yes
Fault tolerant worst event	None	None	None	Yes
Site availability (%)	99,670	99,750	99,980	99,990

In a Tier IV data center, a "system + system" configuration, namely two separate UPS systems, each with N + 1 redundancy, enables infrastructure work to be undertaken without disrupting the critical load.

– Tier I: basic site infrastructure (nonredundant)
– Tier II: redundant-components site infrastructure (redundant)
– Tier III: concurrently maintainable site infrastructure
– Tier IV: fault-tolerant site infrastructure

Power availability increases with tier ranking.

The "dual-cord" IT load innovation enabled the development of the dual bus concept, now used in Tier IV applications. Today, the fault-tolerant Tier IV power infrastructure is very commonly used in critical data centers, even if the data center itself is not necessarily Tier IV certified. This is due to the importance of the protected power relative to its costs. This design is able to withstand a disastrous failure on either side of the supply, it allows concurrent maintenance and it is even possible to undertake infrastructure work on it without disrupting the critical load. This is achieved by implementing a "system plus system" configuration, namely, two separate UPS systems, each with N + 1 redundancy – ie, with enough UPS elements to meet the maximum expected demand, plus one → 3.

Reliability and availability

UPSs play a vital role in ensuring IT reliability and, thus, data availability. As a result, the reliability of the UPS itself is a major consideration. Any time a UPS fails and becomes unavailable, mission-critical electrical loads are put at risk. The surest way to increase availability of power is to optimize the redundancy of the UPS system and to minimize its maintenance and repair time.

Availability, a measure of how good the system is, is formally defined as:

$$MTBF / (MTBF + MTTR) \times 100\%$$

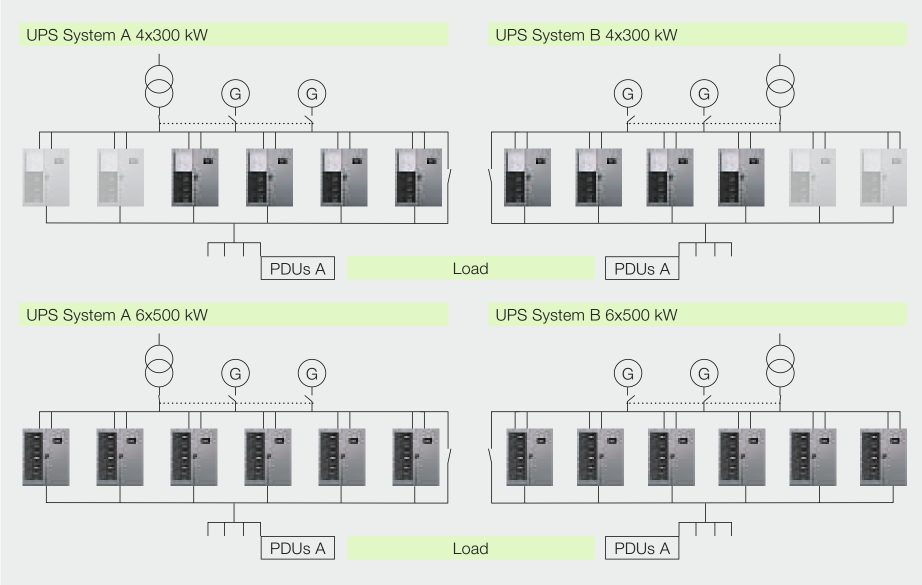
where MTBF is mean time between failures and MTTR is mean time to repair (in hours). These are common parameters in the UPS industry and both impact system availability. Modular UPS designs minimize the system's MTTR.

ABB's Conceptpower DPA 500 UPS, for example, ensures availability and reliability by employing a so-called decentralized parallel architecture (DPA) → 4. In this, each UPS module contains all the hardware and software required for full system operation. The modules share no common components – each UPS module has its own independent static bypass, rectifier, inverter, logic control, control panel, battery charger and batteries.

With all the critical components duplicated and distributed between individual units, potential single points of failure are eliminated. In the unlikely event of one UPS module failing, the overall system will continue to operate normally, but with one module fewer of capacity. The failed module will be fully disconnected and will have no impact on the operating modules.

The ABB Conceptpower DPA modules can be removed or inserted without risk to the critical load and without the need to power down or transfer to raw mains supply → 5. This unique feature directly addresses continuous uptime requirements, significantly reduces mean time to repair (MTTR), reduces inventory levels of specialist spare parts and simplifies system upgrades.

3 Tier IV power system with 6 + 6 UPS units



4 ABB's Conceptpower DPA 500 is scalable up to a maximum power of 3 MW.

UPSs play a vital role in ensuring IT reliability and, thus, data availability. As a result, the reliability of the UPS itself is a major consideration.

This online swap technology, along with significant reductions in repair time, can also achieve so-called six-nines (99.9999 percent) availability – highly desirable for data centers in pursuit of zero downtime.

UPS topologies

Broadly speaking, UPS designs fall into one of three operational architectures: standby, line-interactive and double-conversion online.

Standby (also known as offline) systems are usually low-power (up to 5 kVA) and supply the critical load directly from the mains without performing any active voltage conversion ➔ 6. They transfer the load to the inverter in the event of a bypass supply failure. A battery is charged from the mains and is used to provide stable power in the event of a mains failure.

Like standby models, line-interactive UPSs normally supply the critical load from the mains and transfer it to the inverter in the event of a bypass supply failure ➔ 7. The battery, charger and inverter power blocks are utilized in the same manner as in the offline system, but due to the added regulation circuits in the bypass line, a voltage-regulating tap-changer transformer is often used to handle any small undervoltages and overvoltages that may occur. Thus, the load is transferred to the battery-fed inverter supply less often. The line voltage is actively monitored and when the input voltage or frequency goes out of range, an inverter and battery maintain power to the load.

Line-interactive UPS topologies are usually used for low power ratings (up to 10 kVA), where they often compete with standby UPSs. They are more costly but able to protect the load against long duration brownouts.

There are also larger systems in the market where the tap-changer transformer is replaced with an active automatic voltage regulator (AVR). These line-interactive UPS systems are capable of supplying hundreds of kVA.

The most widely used, in both the power rating (500 W to 5 MW) and application senses, UPS topology is the double-conversion online topology. As its name suggests, the incoming alternating current (AC) is continuously converted by rectifier to direct current (DC) and then back to AC via an inverter. In this way, a perfectly clean waveform can be produced under any mains or generator supply conditions.

This UPS design offers the highest degree of critical supply integrity. The load is supplied with processed power at all times.

Double-conversion topology is used for critical applications like data centers. Its ability to run in load-sharing parallel configurations provides the redundancy that is desired in such applications.

UPS classification

To standardize UPS characteristics, the IEC introduced (in IEC 62040-3) a three-step UPS classification code based on the

5 DPA 500 modules can be swapped without powering down.

operational behavior of the UPS output voltage:
- Step 1: dependency of UPS output on the input power supply
- Step 2: the voltage waveform of the UPS output
- Step 3: the dynamic tolerance curves of the UPS output

These steps are summarized in an AA-BB-CCC-type designator. ABB's UPSs have the top ratings in each and are thus certified as "VFI-SS-111." The designator elements have the following meanings:
- VFI (voltage and frequency independent): The output voltage is independent of all power line voltage and frequency fluctuations and remains regulated within the tolerances set forth by IEC 61000-2-4. Usually, only double-conversion UPSs meet the VFI criteria, while, for example, standby UPSs receive the lowest rating – VFD (voltage and frequency dependent).
- SS: total harmonics factor of the output voltage is less than 0.08 (IEC 61000-2-2) under all linear and under reference nonlinear loads.
- 111: refers to three tolerance curves that describe the output voltage limits versus duration in dynamic situations. The first digit shows the performance at change of operating mode, eg, normal mode – stored energy mode – bypass mode; the second digit the step linear load performance; and the third digit the step nonlinear load performance. Only when this part of the designator is "111" can the user be assured that critical loads will be optimally protected. This expression signifies the quality of output voltage under all operational conditions.

Energy storage systems

Batteries are employed by almost all (around 99 percent) UPS manufacturers to store energy to be used when the power fails or goes out of range. Flywheels, which store energy as kinetic energy, are an alternative to batteries. They are unaffected by cycling, require little cooling, can operate in a broad temperature range. The initial costs of a flywheel system are, however, significantly higher than those of a battery-based system and the load can only be supported for seconds rather than the minutes that a battery system can manage.

Each UPS module in ABB's Conceptpower DPA 500 UPS has all the hardware and software required for full system operation. This ensures full availability and reliability in the event of a failure.

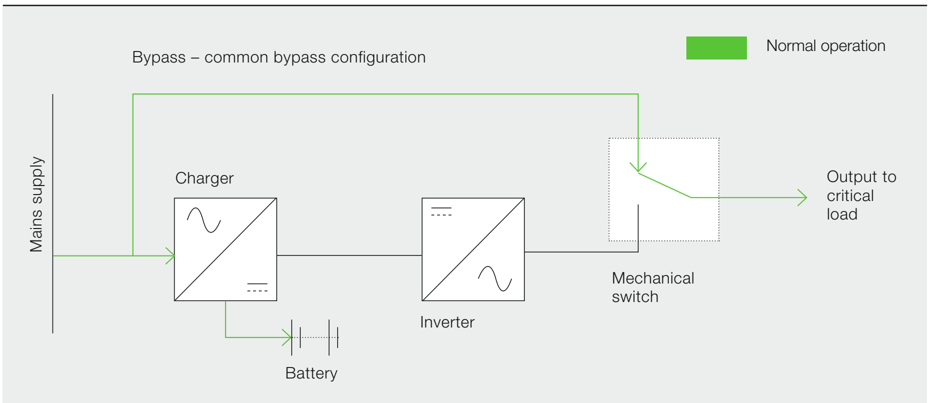
Hydrogen fuel cells exploit the fact that when hydrogen and oxygen chemically combine to produce water, electrical energy is also produced. They are significantly more expensive than batteries. Also, hydrogen is an explosive gas, so great care has to be taken with its storage. However, though in its infancy hydrogen fuel cell technology holds a promise as a power reserve for UPS systems.

Low total cost of ownership

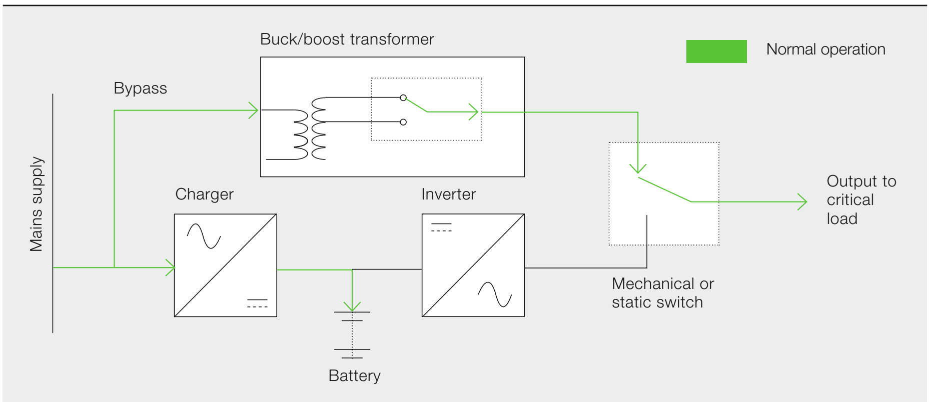
ABB UPSs have a very low cost of ownership, partly because of the modularity and scalability described above, but also because of their best-in-class energy efficiency. ABB's Conceptpower DPA 500, for example, operates with an efficiency of up to 96 percent. Its efficiency curve is very flat so there are significant savings in every working regime. This gives this particular product the lowest total cost of ownership of any comparable UPS system.

The power usage effectiveness (PUE) ratio is a measure used by the data center industry to characterize power efficiency.

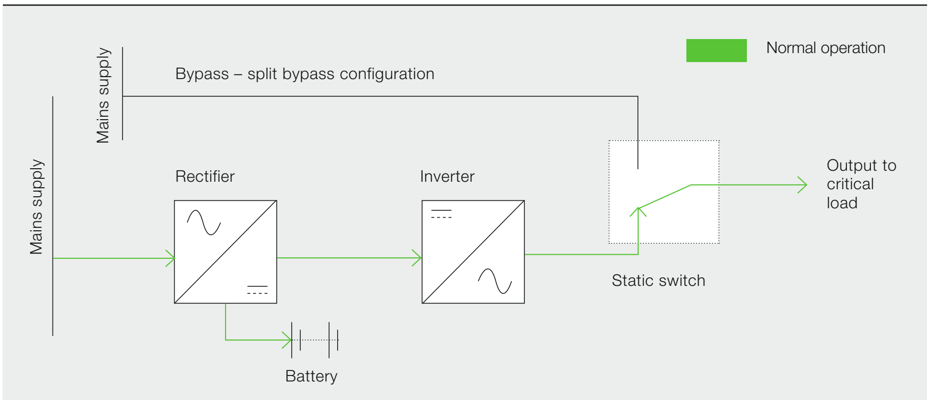
6 Standby UPS



7 Line-interactive UPS



8 Double-conversion UPS



The PUE is derived by dividing the total power used by the facility, by the power used by the equipment related to data storage. Data centers strive for a PUE ratio that is as close to unity as possible and high UPS efficiency helps achieve this.

Further, cooling costs in data centers are substantial. Because they consume less power, high-efficiency UPSs require less cooling effort, creating further savings. ABB UPS solutions also have a very small footprint – ideal for data centers, where real estate can be restricted and expensive.

UPS developments

Data centers are set to increase in size, number and complexity, upping the challenge to UPS products. Also, increasingly sophisticated modular and containerized data centers will require more versatile power protection schemes. But, because continuous availability of power is the sole reason for the existence of UPSs, reliability and maintainability will remain as cornerstones of UPS design.

However, the total cost of ownership and sustainability will drive development toward even more energy-efficient technologies.

Transformer-free UPSs will continue to dominate the market. The footprint of the UPS can be squeezed further, but the copper needed to carry high current cannot. Therefore, alternative or complementary UPS solutions that run at medium voltage (MV) levels will certainly show up. Due to the relatively smaller currents involved, MV UPSs can be built that cater for tens of megawatts. These can then accommodate very large load blocks, or even entire data centers.

Alternative energy sources, smart grids, data center infrastructure management (DCIM) tools, etc., will set new standards. Of course, other concepts as yet unthought-of will arise too – after all, data centers represent one of the fastest-growing and fastest-moving industries on the planet and, as such, are fertile areas for inspiration.

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Continuous power

Digital static transfer switches for increased data center reliability

CHRISTOPHER BELCASTRO, HANS PFITZER – The information flowing through data centers is, in many cases, essential to the smooth running of modern society. For this reason, it is vital that a data center is available at all times. The power grid cannot always be relied upon, and, consequently, every data center has a backup power scheme. When the grid power degrades or disappears this fact must be instantly recognized and the backup power must be brought in so quickly that the changeover is invisible to the data center. Static transfer switches provide an ideal way to do this and these sophisticated products have become an established component of all mission-critical data center architectures.

A transfer switch is an electrical device that switches a load between two power sources either manually or automatically. Thirty years ago, Cyberex, a member of the ABB Group, revolutionized power distribution with its invention of the digital static transfer switch (DSTS). Since then, Cyberex has installed more units than any other manufacturer. The ABB DSTS uses power semiconductors, specifically silicon-controlled rectifiers (SCRs), as high-speed, open-transition switching devices to deliver quality power to a customer's critical load. "Digital" refers to the technologies implemented – namely, digital signal processing (DSP) hardware and patented software that performs real-time analysis of the source waveforms and logic control of the DSTS.

Basic STS characteristics

ABB's two-source DSTSs are designed to power mission-critical loads where continuous conditioned power and zero downtime are required [1,2]. The DSTS is fed by two independent power sources ("preferred" and "alternate") that remain isolated from each another in all operating modes.

The power quality (PQ) on each source is continuously monitored in terms of its voltage, phase and waveform. If a source's PQ falls outside user-defined limits for a set period of time, the DSTS makes the decision to transfer to the other source. Typically, the switching time from the detection of an anomaly to completion of the transfer is one-quarter of a voltage cycle, or about four milliseconds. The switching technique employed is an open transition or "break before make" transfer. In this way, a data center load can be protected from even very short interruptions, or from any surges or sags in the primary power source.

The ABB DSTSs discussed in the subsequent sections are three-phase units operating between 100 and 4,000 A, at 208 to 600 V ➔ 1.

To make the device maintainable without causing downtime, the design of the ABB DSTS includes plug-in style molded case switches (MCSs) that provide isolation for regular maintenance and guided bypass. The MCS provides short-circuit interrupt capability, while eliminating nuisance tripping arising from the lack of an overload trip element. A traditional two-source DSTS incorporates six MCSs: two for source inputs (isolated), two for bypass (maintenance) and two parallel MCSs at the output to ensure no single point of failure through the switching elements and to electrically isolate the SCRs when maintenance is required ➔ 2.

Reliability

The features described above are not the only aspects that enhance ABB's DSTS reliability:

– Type II rated SCRs provide optimal fault clearing capability that coordinates with upstream protection.
– Redundant output switches prevent a single point of failure.
– Infrared ports allow thermal monitoring of critical load connections, without introducing risk by removing equipment panels.
– Redundant power supplies prevent logic failures.
– Redundant cooling fans with failure sensing avoid overheating or load loss due to fan failure.
– Shorted SCR detection prevents load loss should an outage occur.
– Downstream fault detection and isolation prevents the propagation of high-current faults to other upstream distribution systems.

In addition, since 2004 an availability of 99.9999 percent, or "six nines," has been observed for the DSTS. Further, it displays an operating efficiency of 99.60 percent at half load and 99.73 percent at full load.

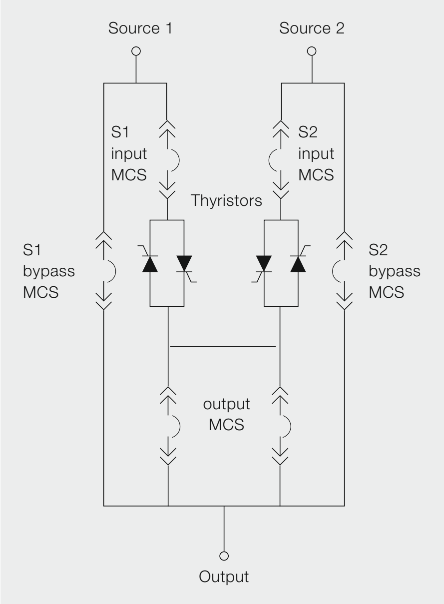
1 An ABB DSTS

The STS is fed by two independent power sources that remain isolated from each other in all operating modes and each source's voltage, phase and waveform is continuously monitored.

Title picture
Discreetly, the ABB digital static transfer switch can instantaneously transfer power sources when the preferred source falters in any way. The end result is continuous conditioned power to a data center's critical load.

With dynamic inrush restraint enabled, peak inrush current can be limited to less than 120 percent of the peak full-load current of the transformer.

2 Single-line diagram of a typical six-MCS STS



Data center availability

In today's business environment, data centers are required to operate at extremely high reliability and efficiency levels. Data center availability, a metric known as "nines" ➔ 3, is generally expressed as:

Availability = *MTBF*/(*MTBF*+*MTTR*)

where:

MTBF = mean time between failures = uptime

MTTR = mean time to repair = downtime.

Thus, as reliability and maintainability increase, so does availability. The need for a common standard to classify data centers' reliability and maintainability became apparent in the mid-1990s. To address this, the Uptime Institute developed a four-tiered classification benchmark that has been utilized since 1995 ➔ 3.

Data center architecture – DSTS relevance

Some simple configurations seen in data centers can highlight the importance and flexibility of the DSTS.

Parallel redundant (N+1) design

In general, an N+1 redundant design consists of paralleled UPS modules of the same capacity and configuration connected to a common output bus ➔ 4a. The configuration is considered N+1 redundant if a system (N) has at least one additional autonomous backup element (+1). The extra UPS module gives better availability than the N configuration and the structure makes expansion easy should facility requirements increase. The configuration does, however, have some disadvantages:

- Single point of failure with common load bus and single-corded loads
- Faults will propagate through each parallel redundant module
- Low efficiency due to light loading on the UPSs
- UPS modules must be the same rating

Distributed redundant design

A distributed redundant, or "catcher," design boasts independent input and output feeds from three or more UPS modules that are coupled with two or more STSs ➔ 4b. Advantages compared with parallel redundant (N+1) architectures are:

- High availability at a lower cost
- Higher efficiency than parallel redundant and 2(N+1) designs
- Increased number of points of conditioned power, through UPS and DSTS
- Faults will propagate through one UPS module only
- Reduces single points of failure

The disadvantage is:

- DSTS cannot support multiple, concurrent UPS failures.

System plus system redundant with no STS (2N)

System plus system redundant (2N) topologies are the most reliable, and most expensive designs in the data center

3 The four-tier classification of data centers

Tier level	Availability (%)	Downtime (hr/yr)	Average downtime over 20 years	Common names	Requirements
Tier I	99.671	28.82	96.07	N	Nonredundant capacity components and single, nonredundant distribution path to server loads
Tier II	99.741	22.69	75.63	Parallel redundant N+1	Redundant capacity components and single, nonredundant distribution path to server loads
Tier III	99.982	1.58	5.26	Distributed redundant	Redundant capacity components and redundant distribution paths to server loads
Tier IV	99.995	0.44	1.46	System plus system multiple parallel bus 2N, 2N+1, 2N+2	Multiple isolated systems containing redundant capacity components and multiple, active distribution paths to server loads

The ABB DSTS can be applied as a two- or three-source utility switch for higher-availability applications.

world ➔ 5a. Typically, dual-corded loads are implemented. Advantages are:
– Separate power sources and paths eliminate single points of failure throughout the architecture
– Redundancy throughout the entire system
– Ability to service upstream equipment like switchgear without going into bypass mode
– Continuous conditioned power

The disadvantages are:
– High cost and large footprint
– Less efficient due to being lightly loaded
– Does not maintain power to both inputs of a dual-corded load in the event of UPS failure

System plus system redundant with STS
By definition, Tier III and Tier IV systems supply continuous power to redundant dual-corded loads. However, they do not provide redundant power availability to dual-corded loads that require quality power to not just one, but both cords continuously. One way to provide this supplementary reliability is by applying STSs ➔ 5b.

The advantages of this approach are:
– Highest level of availability
– Continuous, multiple points of conditioned power
– Separate power sources and paths eliminate single points of failure throughout the architecture (redundant throughout)
– Ability to service upstream equipment, like switchgear, without going into bypass mode
– The STS provides redundancy for dual-cord loads and protects against either source failing
– Effectively removes power quality issues upstream without causing a disturbance downstream

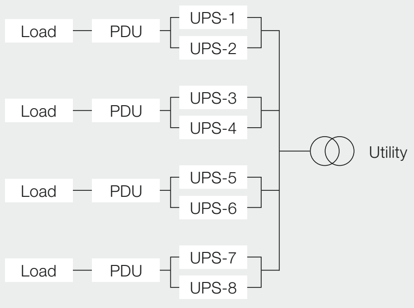
The disadvantages are:
– High cost and large footprint
– Low efficiency due to light loading on the UPSs

Upstream comparisons
Upstream, there will typically be a utility and backup generator, which are switched by an automatic transfer switch (ATS) ➔ 6a. Though low-cost, this solution involves longer contact transfer times, delayed power generation startup and unpredictable generator performance.

The ABB DSTS can be applied as a two- or three-source utility switch for higher-availability applications ➔ 6b. The probability of a simultaneous power outage on a fully redundant, dual-feed system is relatively low. By implementing two independent feeds from separate substations, an ABB DSTS can provide protection, switching power and speeds, and plant-wide distribution efficiencies superior to ATS. Cyberex has installed numerous large DSTSs at power entry points in data centers and industrial facilities. Though

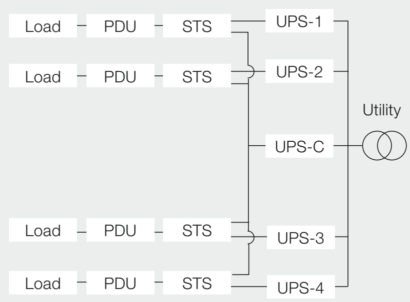
Digital signal processing hardware and patented software performs real-time analysis of the waveforms and STS logic control.

4 Parallel redundant (N+1) design with 4 loads vs. distributed redundant "catcher" design



	Parallel redundant (N+1) UPS – single-corded load
Availability (%)	99.976 (three nines)
Downtime (h/yr)	2.08
Power interruptions/20 yr	6.95
Cost ($)	1.7 million

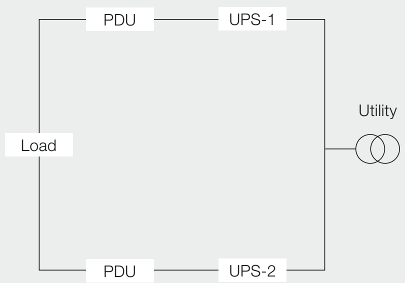
4a (N+1) design



	Distributed redundant catcher with STS – single-corded load
Availability (%)	99.976 (three nines)
Downtime (h/yr)	2.10
Power interruptions/20 yr	6.99
Cost ($)	1.28 million

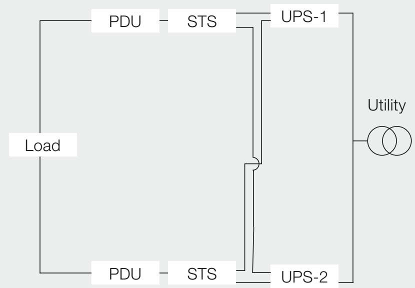
4b Distributed redundant "catcher" design

5 System plus system redundant with no STS vs. system plus system redundant with STS



	Dual UPS – dual-corded load
Availability (%)	99.987 (three nines)
Downtime (h/yr)	1.12
Power interruptions/20 yr	3.73
Cost ($)	460,000

5a System plus system redundant with no STS (2N)



	Dual UPS with STS – dual-corded load
Availability (%)	99.99999 (seven nines)
Downtime (h/yr)	0.0005
Power interruptions/20 yr	0.0017
Cost ($)	540,000

5b With STS (2N)

UPS = uninterruptible power supply / PDU = power distribution unit

more expensive than the ATS approach, and requiring two utility sources, the DSTS approach has many advantages, including:
- Highest level of upstream availability
- The DSTS removes all power anomalies propagated from the utilities and distributes continuous power to all downstream components
- Ability to service one utility source while providing continuous conditioned power from a second utility source
- Extremely high electrical distribution efficiency levels
- Flexibility to add a third source (eg, backup generator)
- Lower cost than UPS

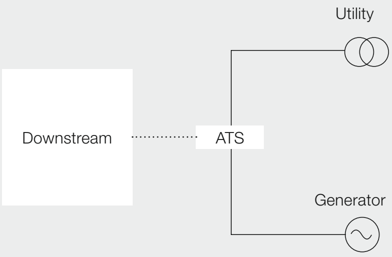
Digital STS advanced features

Apart from the advantages described above, the DSTS has further features worth noting.

Dynamic inrush restraint (DIR)

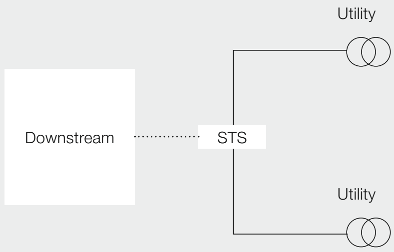
DIR limits downstream transformer inrush current when switching between two sources that are out of phase. This is done by continuously monitoring the transformer flux and precise timing of

6 Upstream comparisons



	One source, one generator - ATS upstream
Availability (%)	99.994 (four nines)
Downtime (h/yr)	0.49
Power interrup-tions/20 yr	1.64

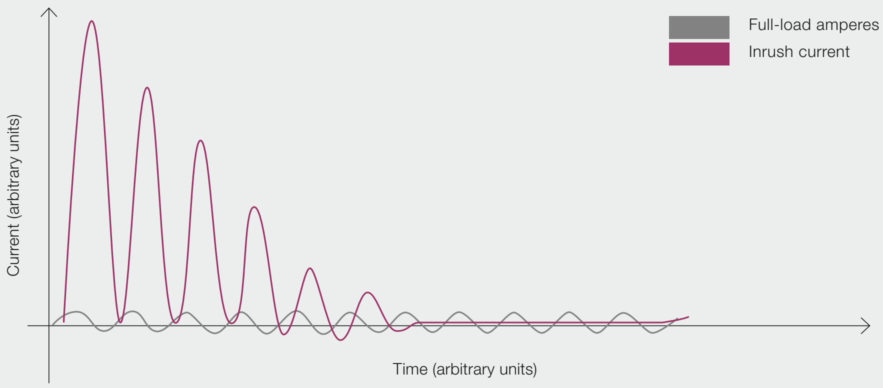
6a Utility and generator with ATS



	Two sources - STS upstream
Availability (%)	99.9998 (five nines)
Downtime (h/yr)	0.013
Power interrup-tions/20 yr	0.044

6b Dual-utility source with STS

7 Transformer inrush current (can be up to 7,200 A for a full-load Ampere value of 600 A) when not using the DIR algorithm.



the transfer so the flux does not exceed the saturation point of the transformer's core. Energizing a transformer results in a potential peak inrush current of 5 to 12 times full-load ampacity (FLA); transferring between out-of-phase sources results in a peak inrush current of up to 20 times FLA → 7.

With DIR enabled, peak inrush current can be limited to less than 1.2 times full-load current of the transformer.

PQ/sensing algorithms

Two DSPs sample the sources 10,000 times per second and utilize patented algorithms to detect source disruptions and failures in less than 2 ms, thus enabling transfers within a quarter cycle.

Smooth transfer

The DSTS source transfer algorithm transfers from an active set of SCRs to an inactive set by removing a gate signal from two parallel-connected, opposite-sense, current-carrying SCRs that, in combination, carry AC in either direction. The transfer process is simple:

1) Removal of a gating signal on the active source, due to the detection of poor PQ or a manual transfer request.
2) Current is sensed through the two active SCRs to determine the current-carrying state of each device over a specific period.
3) Once both states are determined, a gate signal is applied to the corresponding SCR in the inactive set. This enables current flow through this device while simultaneously preventing current from passing between the sources.
4) Once the SCR naturally commutates off, the gate signal is enabled on the reciprocal device to complete the transfer.

Reliability delivers availability

The ABB DSTS can effectively remove upstream power quality issues without causing a disturbance downstream. It can be a cost-effective replacement for an upstream ATS or even a facility-wide UPS system – generating improved levels of reliability while drastically reducing footprint, managing higher electrical efficiencies, and reducing overall cost.

In system plus system redundant configurations, the highest level of availability can be achieved by providing mutual, dual-bus feeds to a DSTS. This architecture provides multiple layers of redundancy that eliminate single points of failure, down to and including dual-cord load power supplies. Finally, a DSTS also provides superior fault isolation and increased protection during maintenance, ensuring continuous conditioned power is delivered to a customer's critical load.

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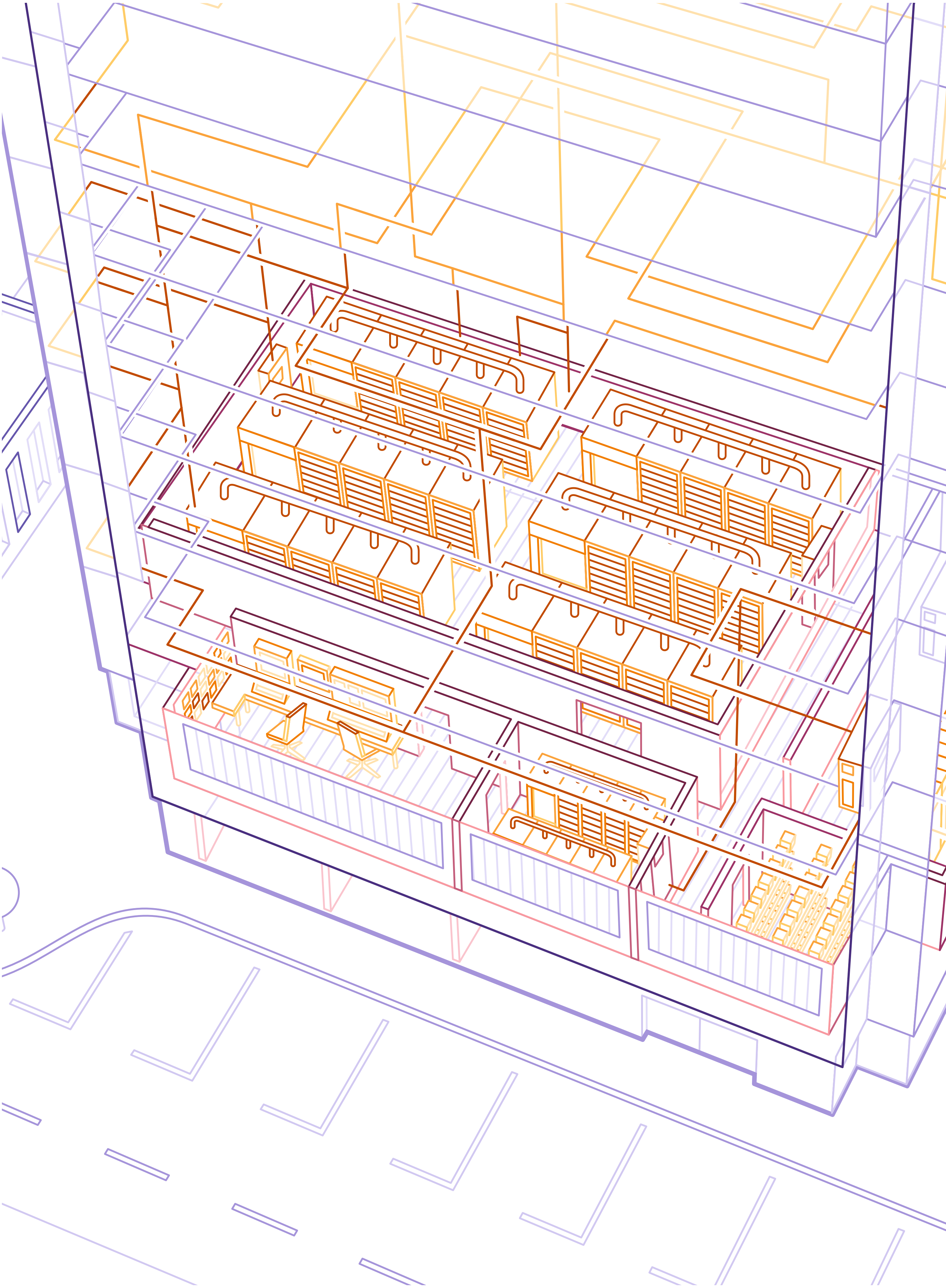
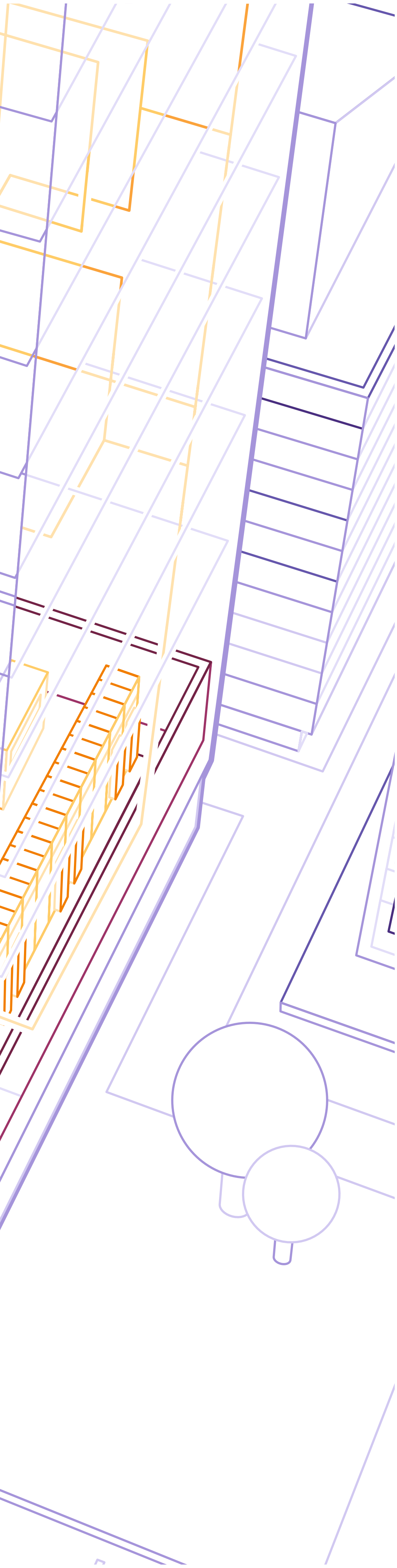




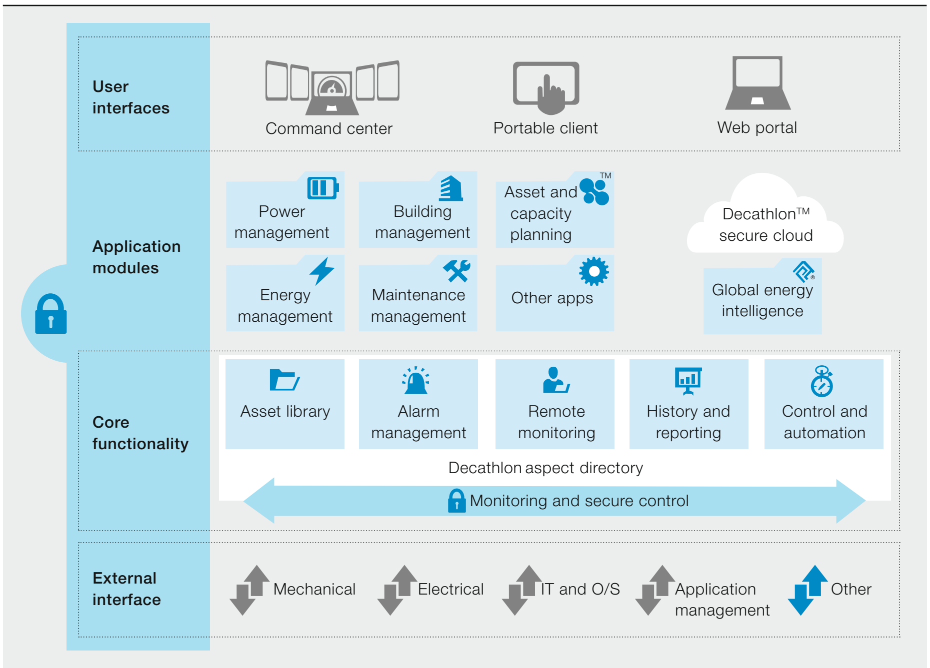
Automated excellence

New concepts in the management of data center infrastructure

JIM SHANAHAN – As data centers grew out of server closets to become the computing titans that now consume over 2 percent of grid power in many countries, they brought with them a legacy of automation systems that they had outgrown but to which they continued to cling. The industry has finally realized that modern data center infrastructure management (DCIM) tools need to provide scalable solutions that bring advanced technologies into play, enabling those who best leverage them to leapfrog their competitors. ABB is helping those customers differentiate themselves in a very fast-moving industry.

Title picture
Sophisticated tools that allow all aspects of a data center to be managed in an integrated way are essential if an operator is to differentiate and survive in the very competitive data center world.

1 Decathlon architecture



Data centers usually operate along lines that mirror their makeup. As a consequence, facility operations (mechanical and electrical systems) tend to run in isolation from IT and server operations. This silo approach makes it difficult to get an overview of what is happening in the data center as a whole, even though most critical decisions need to take account of the entire picture.

ABB has brought its best practice solutions from other industries and merged them with new data-center-specific libraries and applications to form Decathlon.

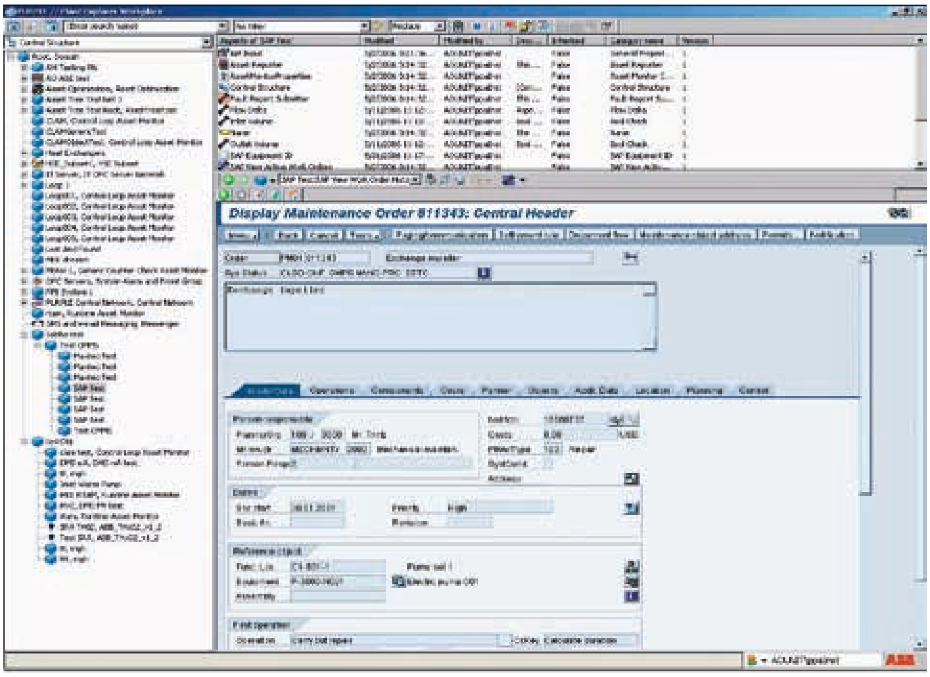
Initially, DCIM may seem confusing because the term is used so broadly. However, the definitions of DCIM published by leading industry research firms concur that:

- DCIM requires instrumentation in order to gather and normalize data center metrics.
- DCIM analyzes this data and provides actionable information about data center management.
- DCIM is not a standalone solution, but a component of a comprehensive data center management strategy.

To the IT engineer, DCIM can be a tool to manage server location, configuration and application load; for the facilities manager, it can be a system to control and monitor electrical and mechanical equipment; to a senior manager, it can be a way to compare data centers and leverage business intelligence. ABB's DCIM product, Decathlon™, is one of the most advanced DCIM solutions on the market today. Delivered via hardware and software, the Decathlon system provides the tools to manage a flexible network of power, cooling and IT equipment. The information is presented in a single operational environment and via a single data source, which helps overcome information barriers. Both IT and facility personnel can work together more effectively – sharing a "single truth" from which they can index and report their data center improvements.

Decathlon takes automation lessons learned from process industries and applies them to data centers.

2 Decathlon workflow integration – CMMS work order



Decathlon also offers advanced control, maintenance management, strategic energy procurement and the ability to shift computing loads between data centers based on the cost or availability of energy.

More recently, fully featured converged DCIM solutions have emerged that offer end-to-end visibility. Whoever pays the power bill can now measure data center efficiency in terms of workload-per-kWh – for example, the number of SAP transactions per MW or the number of e-mails processed per dollar. This visibility provides new leverage for data center owners and operators, and drives efficiency in the data center organization. ABB has brought its best practice solutions from other industries and merged them with new data-center-specific libraries and applications to form Decathlon → 1. As well as "normal" DCIM functions, Decathlon also offers advanced control, maintenance management, strategic energy procurement and, through a concept known as software defined power, the ability to shift computing loads between data centers based on the cost or availability of energy.

Essentially, a data center converts power to transactions and generates a lot of data and heat (that has to be removed) in the process. It is instructive to look at this entire chain of events in a little more detail to understand some of the mechanisms involved, some newer ideas around how they can be managed and the value of a converged DCIM solution.

Keeping cool

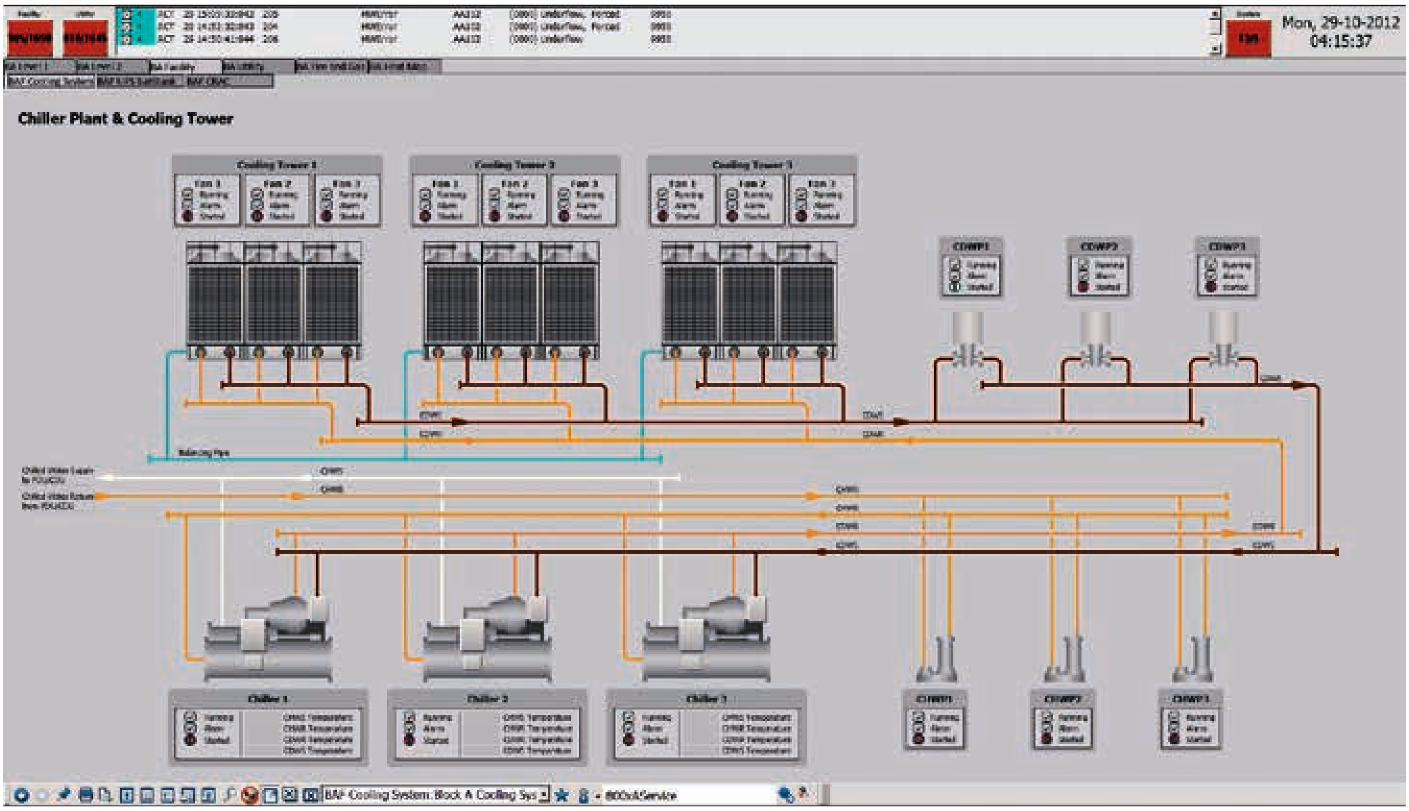
The starting point for a DCIM project is often a need to control or monitor the physical environment around the servers. In recent years, it has become popular to raise server inlet temperatures to achieve higher efficiency because less cooling is then required. It is not uncommon now to find "cold aisle" temperatures at server inlets in excess of 27 °C. This means the "hot aisle" at the server outlet can exceed 40 °C. ABB robots are being considered for some duties, such as moving servers or cables, in the hot aisle, where humans cannot comfortably operate.

In these extreme environments, tight control of temperature is critical to ensure the server does not overheat. One way to achieve such control is to look not just at the environmental temperature sensors around the racks, but to look at onboard server temperatures too. This means reading CPU temperatures from each server via a simple network management protocol (SNMP), then averaging this across each rack of, typically, 30 to 40 servers. By controlling the environment based on CPU temperature – the hottest part of the data center – higher efficiency can be achieved and problems with individual servers can be detected early. (See article on data center cooling on page 52 of this issue.)

Building management

A building management system (BMS) monitors and controls the environmental and safety systems – such as those for lighting, ventilation and fire – in a large building. As concerns about energy conservation gained critical mass, BMS feature enhancements evolved to become more aligned to energy efficiency. However, a BMS cannot cope with the rapid and dynamic expansion (and consolidation) of data center operations where data from onboard sensors in thousands of servers at multiple sites are factored into uptime and optimization strategy and tactics. Decathlon, which is built on the ABB Extended Automation System 800xA platform, collects, normalizes, records and analyzes the large amounts of data from both IT and facility systems. Furthermore, Decathlon exploits its rich history in control

3 Chiller overview graphic



technologies and automation, such as advanced process control, autotune and advanced alarm handling, to optimizing the data center. For the purpose of data center performance monitoring and optimization, a traditional BMS is more problematic and expensive because it is not designed for broad and granular data capture, analysis and user configuration.

Decathlon tracks server location to automatically allocate a new server to an optimal rack position to make best use of available power, cooling and network connections.

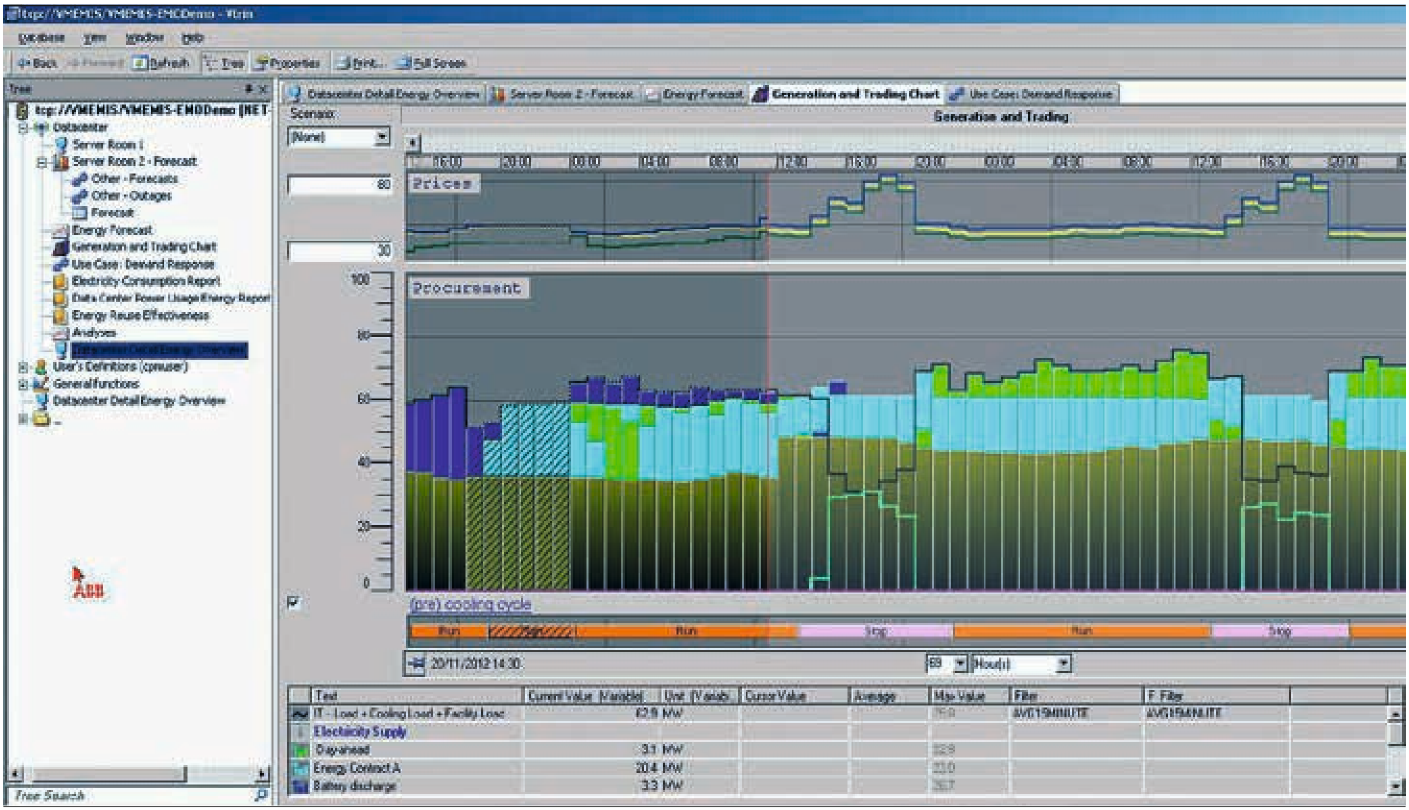
Power monitoring

On the electrical side of the facility, the power chain from pylon to processor provides a myriad of opportunities to monitor and optimize. Decathlon does not just measure and report on power from installed meters, breaking data down by user, area and source, it also analyzes power quality events such as spikes, manages breakers for load shedding or alarming, and provides visualization of the entire power tree from the grid connection right down to each server motherboard.

Capacity management

From the time a server enters the data center in a box to the time it is decommissioned three years later, it goes through many stages of racking, imaging, burn-in, power and network allocation, live deployment and so on. All these stages need to be tracked and managed. To accomplish this, an asset management and capacity planning application is employed. Decathlon uses Nlyte or other technology partner solutions and synchronizes the server location information with its internal database. This application can automatically allocate a new server to an optimal rack and position within that rack to make best use of available power, cooling and network connections. This can extend the life of the entire data center by ensuring that all available capacity is used and that there is no “stranded” power, cooling or network capacity. The

4 Generation and trading chart



system also issues work orders to manage the entire process for server additions, moves or changes, and can track which virtual machines, operating systems and applications run on each physical "server metal." By combining the asset management system's knowledge of server physical location and connections with the real-time information on the server's environment and onboard parameters, Decathlon can close the control loop to provide tight control and advanced reporting across the traditional silos of facilities and IT operations.

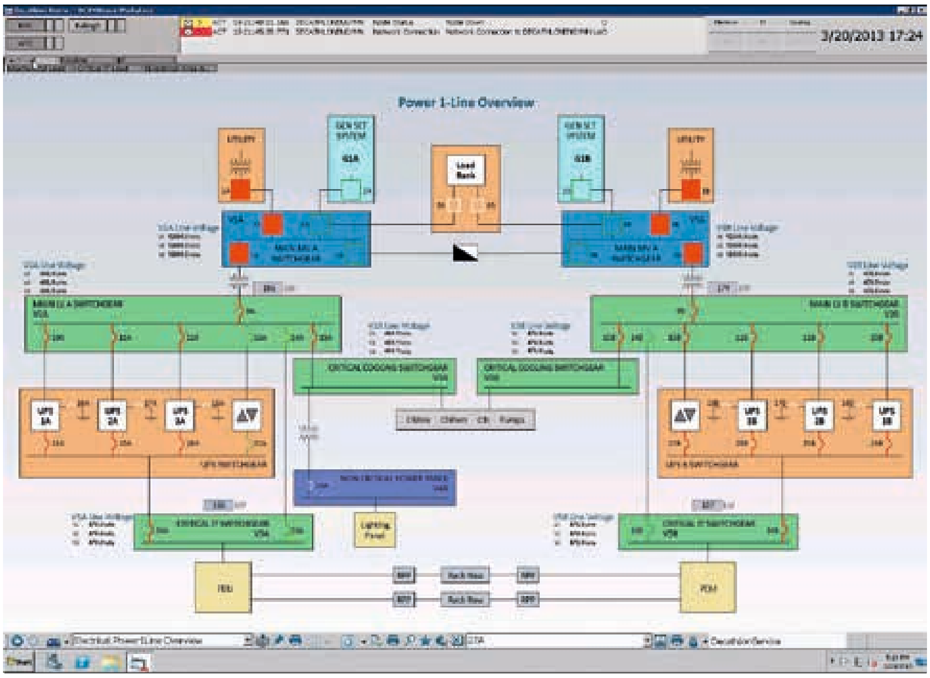
Asset health

Apart from IT assets like servers and network switches, a normal data center has standby generators, UPSs, batteries, switchgear, chillers, pumps, computer room air handlers or conditioners (CRAHs or CRACs), fire detection and suppression systems, access control systems, leak detection systems, etc., all of which have regular maintenance requirements. Decathlon can be interfaced with some industry-standard computerized maintenance management systems (CMMSs) such as SAP or Maximo or it can be bundled with an ABB CMMS such as ServicePro or Ventyx Ellipse → 2. Decathlon can deploy asset monitors on critical equipment items to ensure they are operating correctly. Should they start to drift outside acceptable limits, a maintenance work order can be raised even before the equipment itself goes into an alarm state. This condition-based maintenance is further enhanced by Decathlon's remote operations center (ROC) service where data center subject matter experts (SMEs) are on hand to prevent an incident from escalating to an outage by assisting the responding technician.

By controlling the environment based on CPU temperature, higher efficiency can be achieved and problems with individual servers can be detected early.

Compute load can be shifted from one bank of servers to another, or from one data center to another, to save energy or for reasons of cost or availability of power.

5 A typical data center power one-line diagram in Decathlon



Moving loads

Decathlon can monitor CPU utilization across all of the servers in a data center, or across multiple data centers. In a process known as run book automation, and through integration with virtualization solutions, compute load can be shifted from one bank of servers to another, or from one data center to another. This can be done to save energy, where the unused servers are put into a sleep mode, or for reasons of cost or availability of power. Global energy intelligence (GEI) provides a data center owner with a single interface to all of the world's energy markets so that IT loads can be shifted between data centers based on power market or demand-response opportunities. ABB's investment in Power Assure, a company based in Santa Clara (United States), delivers GEI, run book automation and power capping to Decathlon. Energy market pricing and trading facilities can also be provided to Decathlon through the Ventyx suite of products.

Clever energy

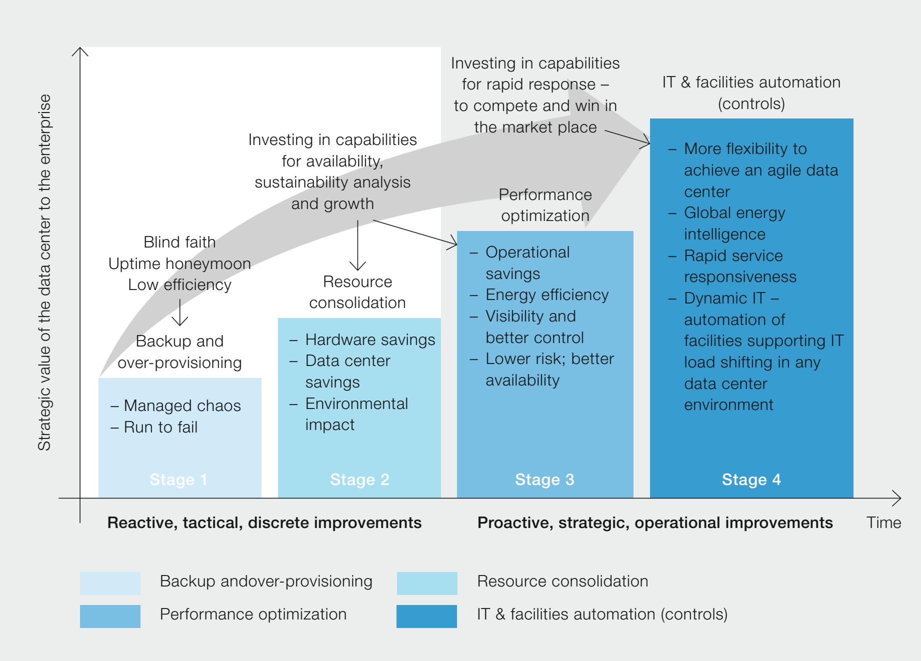
Decathlon uses the features of Energy Manager, a solution successfully used in pulp and paper and other industries, together with GEI to help data centers minimize their peak demand, or to make revenue from their grid connection – for example by using their standby generators to sell power back to the grid under a demand-response program. In this instance, rather than perform monthly generator tests where the power is dissipated into a load bank, the generators are run when needed by the grid and the owner can earn significant revenue. This bidirectional grid connection also significantly improves the resilience of the data center over a conventional automatic transfer switch (ATS) arrangement.

Server efficiency can also be increased by using server "power capping," where a limit is imposed at certain times on the power that can be drawn by CPUs performing noncritical functions. Increased utilization can be achieved without increased risk by balancing compute infrastructure with actual demand. Decathlon determines the optimal capacity required for a given IT load and dynamically adjusts server availability in real time along with required cooling and facility resources. This, in turn, results in significantly increased operational efficiency and decreased energy costs. (Please refer to the article on data center design optimization on page 48 of this issue of *ABB Review*.)

High visibility

Decathlon presents all of this information to the user through a "single pane of glass" → 3–5. Basic measures of data center facility efficiencies like power usage effectiveness (PUE) are supplemented in Decathlon's configurable dashboards and reports by more com-

6 The data center maturity model



prehensive metrics like corporate average data center efficiency (CADE) that calculate efficiencies by taking server utilization into account. The jury is still out as to which metric will replace PUE as a more comprehensive data center efficiency indicator. However, with its end-to-end visibility, Decathlon offers the data center owner or operator a unique and comprehensive view into their systems with the possibility to configure custom performance indicators.

Apps and modules

Decathlon is a modular system, meaning that once the core system is installed, additional application modules can be added easily. In practice, each application enhances and leverages the core database so that as mechanical, electrical or IT equipment and systems are added, the visualization, reporting and analytics applications can provide a more comprehensive picture of the data center. This means that as a data center starts to deploy a DCIM solution, it can progressively move up the data center maturity model in manageable steps, rather than have to deploy everything at once. Most owners starting a DCIM deployment will be at stages one or two of the model → 6.

> Decathlon helps minimize peak demand or helps generate revenue by using standby generators to sell power back to the grid under a demand-response program.

An existing facility operator may have had a couple of years of "uptime honeymoon" with a new facility before gradually realizing that more attention to real-time monitoring and maintenance is required to avoid incidents and outages. In this instance, a power management solution can improve uptime by providing early warning of issues like breaker trips or power spikes before they cause outages, while asset monitors can prevent outages on critical equipment through condition-based maintenance. A more mature operator can turn his grid connection from a cost item to a source of revenue while increasing uptime by installing a bidirectional grid connection and participating in automated demand-response programs.

The underlying trend in data centers today is that over-provisioning of equipment is being supplanted by software resilience. The future – where entire data centers go on a standby mode and consume no power or where an entire compute load can be seamlessly shifted from one data center to another based on energy availability or cost – is today's emerging reality. And it is all enabled by DCIM.

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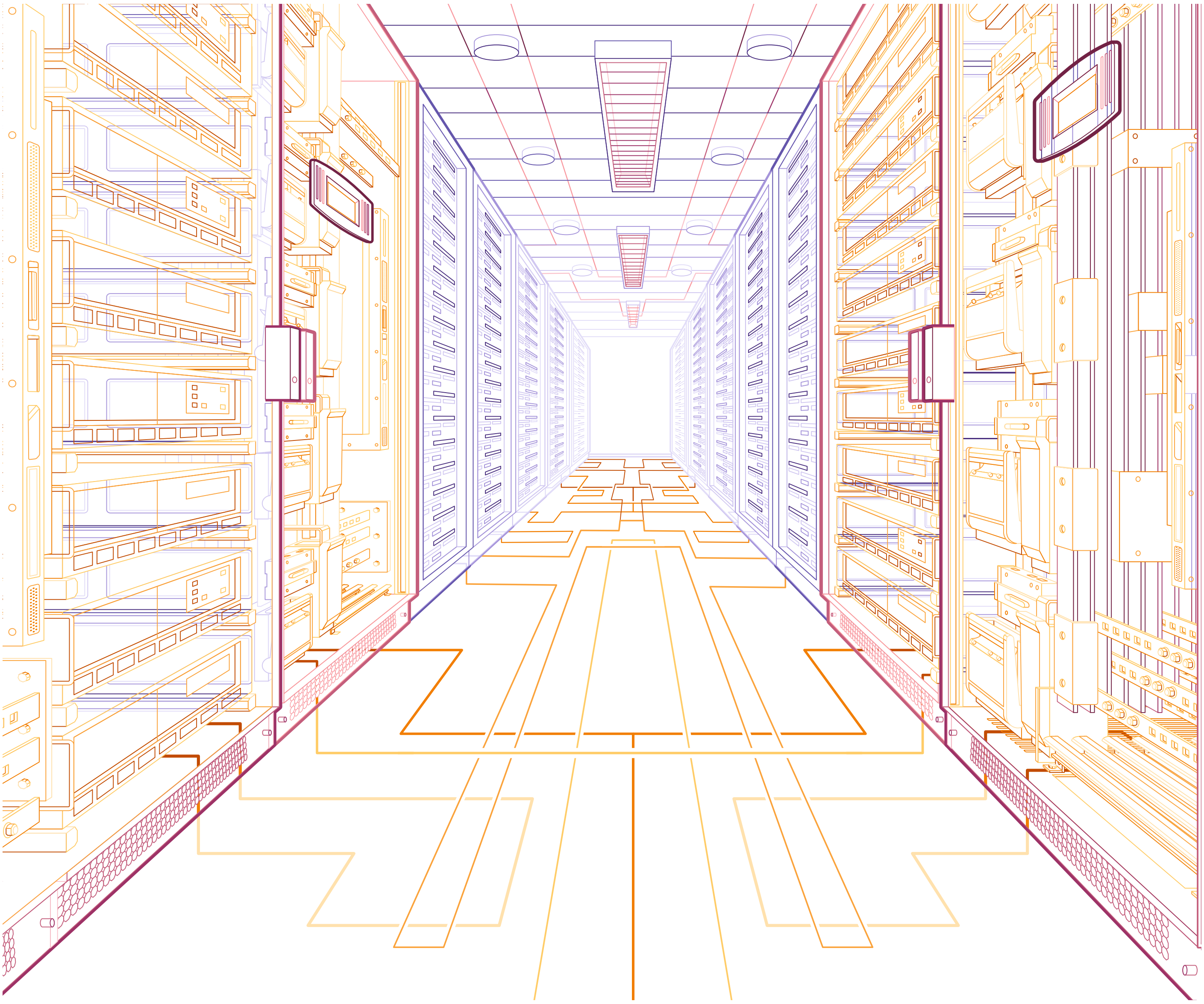
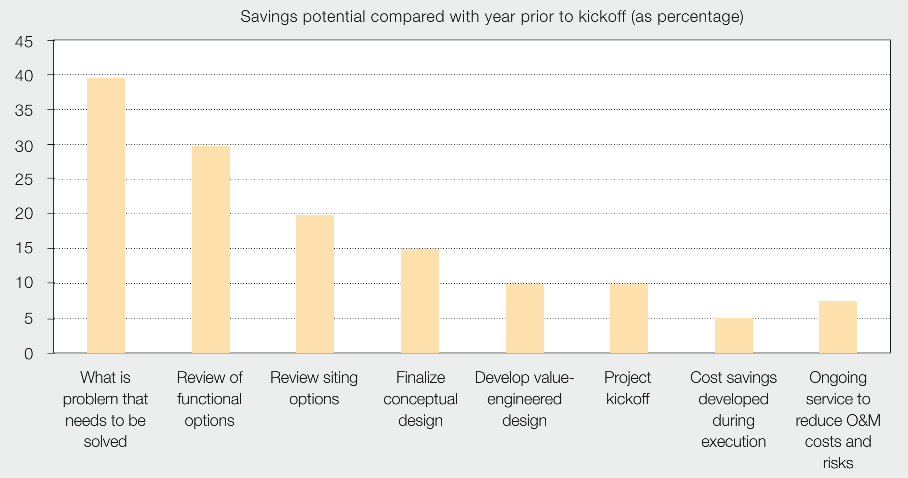


Design decisions

What does ABB contribute to the design of data centers?

PATRICK KOMISCHKE – Design should always be driven by the purpose of the end product, and this should be reflected in the requirements of the customer or end-user. These requirements, including codes and industrial standards, are combined with the capabilities and competences of the supplier to create the product. The design of the electrification of data centers occurs in a very dynamic environment. It is not a completely new field of engineering, but the range of design approaches and the rapid development of technologies and customer requests create numerous challenges. This is reflected in the fact that various standards for data center design exist.

1 Advantages of ABB's systems approach



- Lower project risks.
- ABB systems project awarded on a firm lump-sum basis (ABB paid for results, not effort).
- One integrated project schedule coordinated with customer and owner engineers.
- ABB system model reduces the number of companies involved in the project, hence fewer interfaces to coordinate.
- ABB experts support the project organization in all disciplines.
- ABB projects feature direct involvement of ABB factory personnel.
- An ABB Manager at each ABB factory is responsible for equipment to be delivered.
- ABB system approach reduces delivery challenges by securing priority production slots from its factories.
- ABB system projects reduce emergent technology risks by accessing factory experts on a real-time basis.
- Lower awarded costs.

ABB provides a mix of global equipment technology, project execution expertise, project/discipline/product engineering along with the expertise of integrating third-party contractors to deliver the optimum mix of technology, project engineering, project management, and local expertise for the most cost effective solution.

- Lower customer project management costs.
- Lower project execution costs.
- Lower customer warranty, operations and maintenance costs.
- ABB has expertise in a broad range of fields.
- ABB has global expertise in the data center industry.
- Technical experts from different disciplines and factories. ensure the best solution from a single source.
- Lower cost of ownership (see inset graphic).

At the beginning of the design process of a data center are the identification of the load requirements that the center will need to handle and the required reliability. The reliability definition is interpreted in the context of the Tier concept. Additional parameters to taken into account are geographical and physical locations as well as security aspects and required compatibility with other systems.

A typical design starts at the high-voltage (HV) connection where the power is drawn from independent sources. Power sources can be utilities or independent energy suppliers. From here, the power passes through the medium- and low-voltage (MV and LV) distribution, which connects and combines different sources while feeding and supplying the energy to the points where it is required: primarily the server racks but also all the auxiliary systems supporting the reliable and safe operation of a data center. These are mainly hardware implementations, but to ensure a smooth integration and cooperation, several control systems based on different software platforms are used to combine these components.

The handling of this huge span of disciplines and technologies requires an organization covering a broad palette of engineering resources and the associated expertise under one umbrella. It is furthermore important to work closely with the customer in the selection of the optimal design.

Why is the ABB approach different?

ABB draws on a comprehensive and long experience as a product supplier for data center applications. In recent years increasing efforts were made to package these products and to offer customers a broader product portfolio from a single supplier. The real potential and advantage of ABB's offering, however, lies is in the OEM (original equipment manufacturer) systems approach. Here, the full strength of the company's wide product portfolio is paired with the competence of an OEM system integrator. This means that the products do not only come from a single company, but are integrated into one system and supplied to customers from a single source.

The acquisitions ABB made over recent years have expanded the company's product portfolio further, meaning the company can now cover almost the full spectrum of data center electrification. Indeed if there is a gap, the systems approach ensures that a third party product can be selected and seamlessly integrated with ABB's offering.

The systems approach, which is equal to an EPC (engineering, procurement, construction), offers significant advantages to customers or investors in the data center industry → 1–2.

Title picture

The design of a data center is not only about choosing between myriad competing suppliers and their products, but also between different design and operational philosophies. Decisions made at an early stage will have implications and repercussions throughout the life of the data center. So what is the best way through this labyrinth of decisions?

2 Traditional outsourcing options

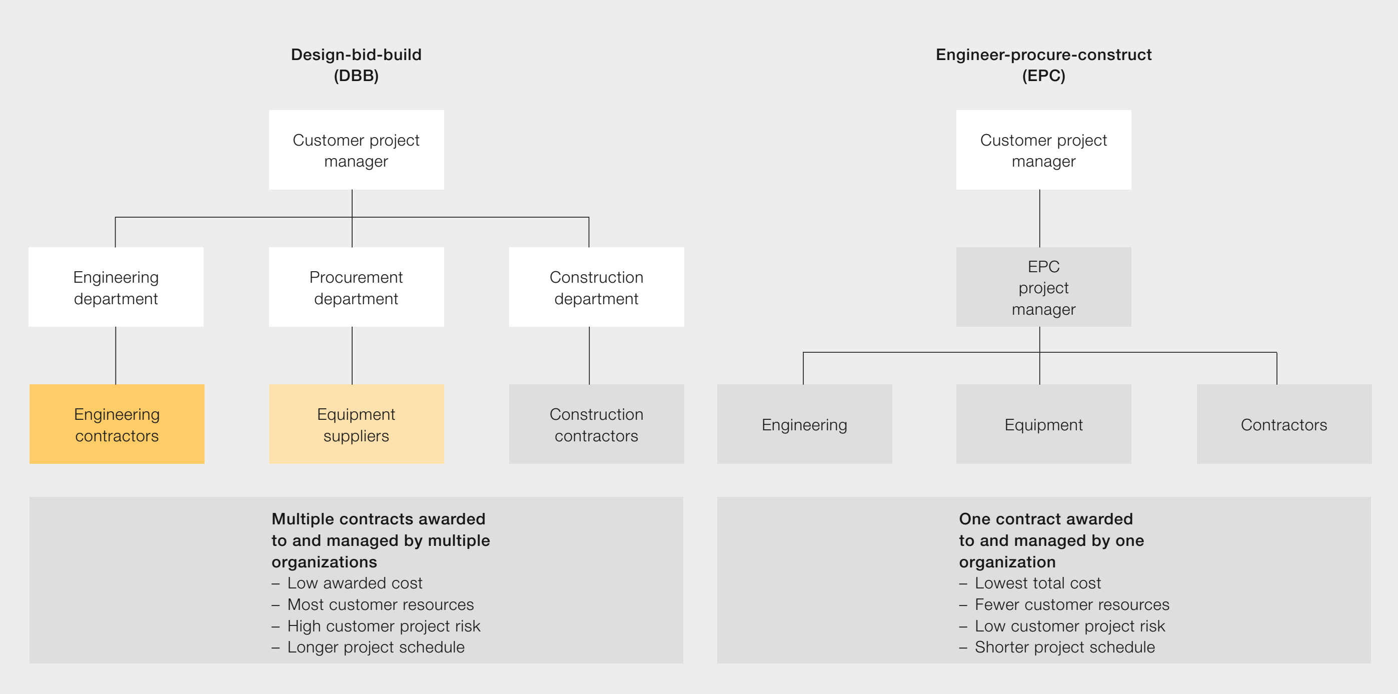


ABB can now cover almost the full spectrum of data center electrification.

Internal ABB project

To test and cement the systems approach, ABB began an internal project in 2012 with the goal of designing a 20 MW Tier III data center design with maximum ABB content, while remaining as close as possible to market typical solutions.

Technical experts from different disciplines and factories. ensure the best solution out of one hand.

The target was to ensure the systems approach by using ABB products as well as products from the recently acquired companies, Baldor and Thomas & Betts, and integrate them into an ABB data center solution.

The project's specified deliverables were single line diagrams, physical layouts, specifications and other supporting material that could be used as a basis to deliver both data center equipment and integration out of one hand (the system approach) while being closely attuned to customer and market requirements. This internal project led to a successful market introduction of the defined system approach.

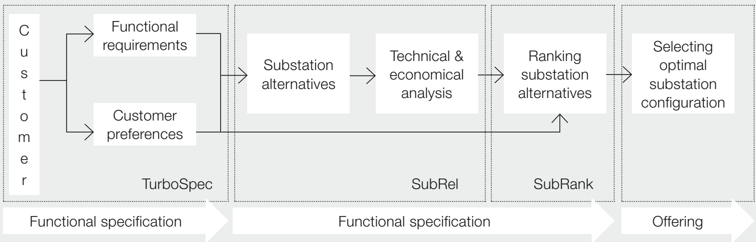
Design approach in detail

Starting on the HV side, the design had to consider different solutions such as air- and gas-insulated switchgear (AIS and GIS) → 5, different transformer types, and control systems – to ensure reliability but also correct connection and grid integration on the utility side. The AIS vs. GIS comparison is a widely discussed topic and a very good example for demonstrating the advantage of a system approach. Before committing to a decision, ABB is able to look at the grid where the data center should be integrated and make a recommendation in collaboration with the customer and the related utility. An example of the evaluation process is shown in → 3. Conclusions of this evaluation are shown in → 4.

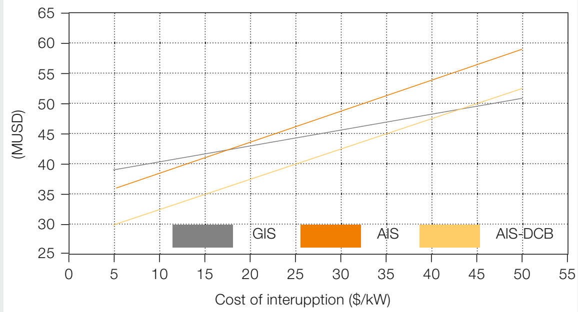
In addition to the system/grid analysis, other factors such as physical location and safety requirements can play a role. An example of a physical AIS vs. GIS comparison (showing significant space savings) is shown in → 5.

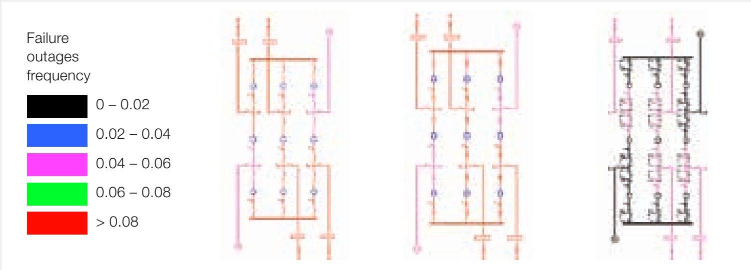
The same design steps and analysis are also applicable for the MV side, but in addition, the integration of loads and subsystems such as generator sets, needed to be

3 Substation optimization process



Methodology major pillars
1 Collecting S/S functional requirements
2 Identifying S/S alternatives
3 Reliability analysis
4 Economic analysis
5 Ranking S/S alternatives
6 Selecting optimal S/S solution





Configuration Type	Total OF /yr	Total OD hr/yr	Failure OF /yr	Failure OD hr/yr	Maint. OF /yr	Maint. OD hr/yr
AIS	0.94748	14.57	0.09748	3.17	0.85	11.40
AIS-DCB	0.54136	13.01	0.09136	3.21	0.45	9.80
GIS	0.36770	12.69	0.05100	3.16	0.32	9.53

4 Assessment process tools

Captures customer objectives

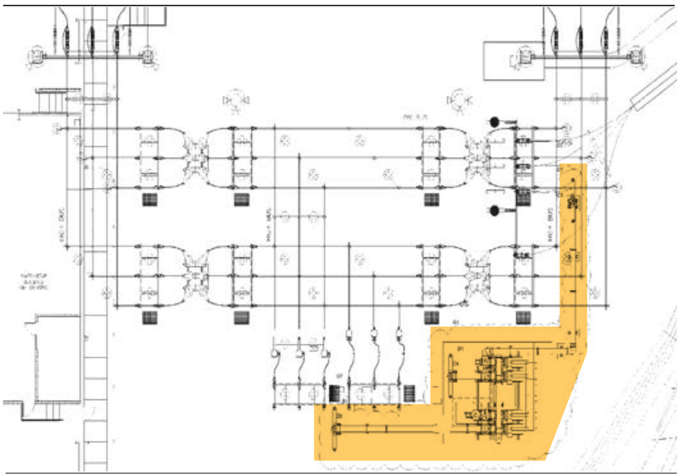
Life cyle cost
– Initial capital costs
– Reliability cost
– O&M cost

Performance
– Flexibility
– Safety
– Automation level
– Technology vintage

Environmental factors
– Ecological impact
– Air pollution tolerance
– Appearance/aesthetics
– Audible noise generated
– EMF fenerated
– Radio/television
– Interference generated
– Disposal concerns

Ranks power system alternatives

5 ABB high-voltage gas-insulated switchgear (actual AIS footprint vs. GIS footprint)



GIS substations cover approximately 15 percent of comparable conventional substation footprint while delivering increased reliability.

considered as options. Decisions such as indoor vs. outdoor, physically together with the data center or not, noise, safety etc. must be reviewed and answered. ABB also provides the full expertise to integrate this part into the optimal solution.

The numerically most significant selection of ABB products and variants considered in this internal project were those on the LV level and the interface to the server structure (where ABB offers vast experience in the data center industry). There remain, however some gaps where ABB has no products to cover a given function or a product exists that would be difficult to integrate. Here again, the systems approach displays its value as ABB can support decisions on integrating a third party product or launch an internal development effort.

Beyond the traditional HV/MV/LV disciplines, ABB's portfolio includes other products and software solutions that fit in the data center landscape and can be used to combine, connect or extend the above solutions. A notable part of this category is ABB's systems integration expertise that can combine products to a system. By focusing on the systems approach and drawing on the full knowledge from across the company, an optimal solution can be delivered to every customer.

Looking forward

Facing the constraints in the electrical infrastructure sector, such as limited qualified in-house resources, customers are increasingly seeing the value offered by ABB's systems approach. Opportunities, however, will still remain for customers interested in ABB's products and seeking to combine them with solutions in-house.

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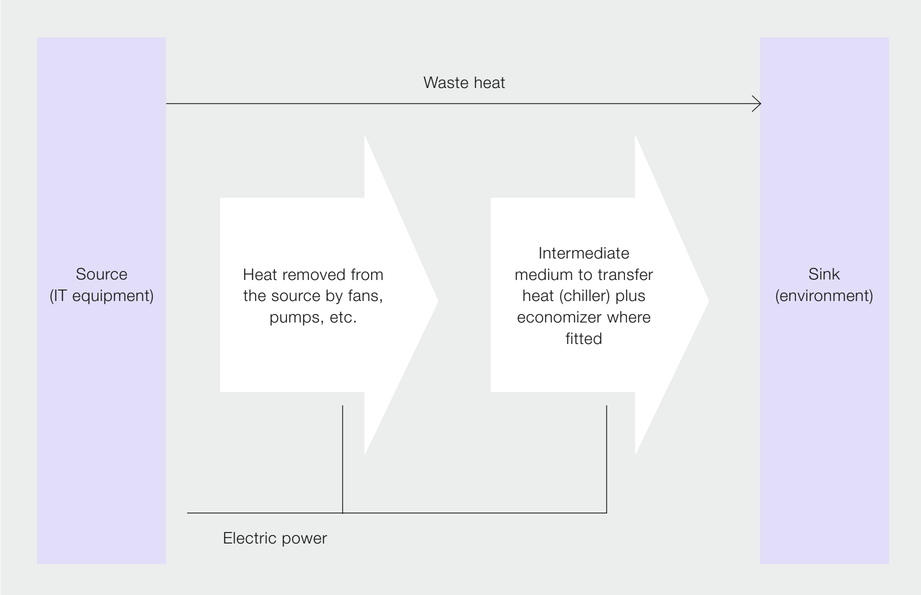
Keeping it cool

Optimal cooling systems design and management

SHRIKANT BHAT, CARSTEN FRANKE, LENNART MERKERT, NAVEEN BHUTANI – Heat generation is a cause for major concern in data centers. Indeed, up to 45 percent of the total energy used in a data center can go to just cooling the server racks [1]. This figure is set to rise as servers become ever more compact and, as a result, power densities increase. Cooling technologies, power management and associated control systems are rapidly evolving to combat this escalating heat problem. A modern cooling system that can rise to the challenge of this situation must adopt a radical approach and focus on improved energy efficiency, integrated management and high reliability for the entire data center. ABB's experience in managing critical power systems and complex industrial processes stands it in good stead to take up the cooling challenges a data center presents.

Title picture
A large part of the energy consumed by a data center ends up as waste heat. Dealing with such a large heat load in such a small volume requires sophisticated cooling technology and techniques.
Photo courtesy: © 2013 Michelle Kiener

1 Heat flow in data centers



Until recently, heat management techniques in data centers were based on the methods used to cool buildings. Thermally, a server was treated as an "equivalent human" and this assumption worked fairly well. However, the heat flux from commercial microprocessors has increased from around 1 W/cm² to 100 W/cm² over the last decade and this is expected to rise further [2]. This represent a massive increase on the demands faced by any cooling system.

Cooling in data centers involves the transfer of heat generated from IT equipment (source) to the environment (sink) in a two-step process: The heat is first transported by a medium (air or liquid) out of the server racks and then it is rejected to the environment ➔ 1. Both these steps consume electrical energy. The target of cooling efficiency measures, then, is to reduce the energy required to remove the heat and recover and reuse as much of it as possible. This can be achieved through innovations in the design of the cooling system itself as well as by inventive operating strategies – eg, smart sensing and monitoring, and integrated system management.

Cooling system design and management has several important areas and it is worthwhile to examine each of these ➔ 2.

Novel cooling designs

There are various cooling technologies at different stages of commercial maturity and some of these show promising results ➔ 3. Aisle containment, for instance, is practiced commercially and can improve system efficiency by up to 30 percent [3]. On-chip cooling is at a preliminary research phase and has been reported to achieve cooling of up to 15 °C for heat fluxes as high as 1,300 W/cm² [4]. Liquid cooling is expected to reduce cooling energy consumption by as much as 50 percent compared with conventional air-cooled systems and is being commercialized now. Membrane air drying and evaporative cooling is reported to reduce energy requirements by up to 86.2 percent compared with conventional mechanical vapor compression systems [5].

The waste heat from a data center can be augmented by solar thermal energy to drive an absorption chiller, thus reducing power usage effectiveness to less than one (absorption chillers use the hot water from the primary cooling loop, and solar heat on occasion, to drive an additional chiller loop).

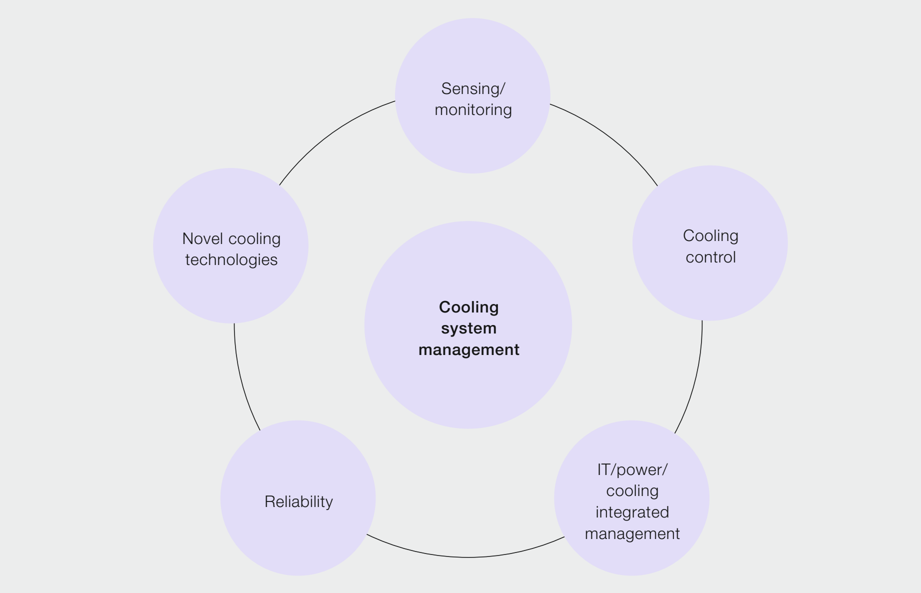
Liquid cooling, absorption cooling and evaporation-based cooling have already been practiced in other industries. However, data centers pose unique challenges in terms of the nonhomogeneous heat generation associated with highly dynamic load behavior and the requirements for high reliability. ABB has expertise in ensuring high reliability for critical power system components along with extensive experience in integrated process management. This capability can help address the challenges posed by integration of novel cooling technologies with data centers.

Monitoring and sensing

The first step in managing and controlling cooling is to monitor the thermal behavior of the data center. Hot spots are a major cause of concern and these can be detected using infrared sensing or wireless sensors. Soft sensors that combine data already available with detailed computational fluid dynamics models, or empirical models, are another important tool.

> The clear target of cooling efficiency measures, then, is to reduce the energy required to remove the heat and recover and reuse as much of it as possible.

2 Focus areas for cooling system management



IT load management is often decoupled from the cooling and power systems – so IT jobs are started with no regard for the cooling or power required. To avoid this, coordination of all three subsystems is required.

It is also important to benchmark emerging technologies:
- What are the current cooling technologies and their limitations?
- What advanced solutions can be integrated with the cooling system?
- Up to what level is integration or adaptation feasible and what are the system limitations?
- What is the impact of a new solution on the reliability of the overall cooling and IT system?
- What will be the value (cost benefits, return on investment, etc.) of the newly added resource?

ABB has demonstrated the use of concepts such as infrared sensing, wireless communication, soft sensing and fingerprinting across different application areas in the power and automation domain. This know-how can be extended, with suitable adaptations, toward data center performance monitoring.

Cooling control
A data center cooling unit has a chiller, cooling tower, pumps and thermal storage → 4. It often also has an economizer, which provides a form of "free cooling." Economizers complement the existing cooling by drawing in colder outside air and using it to reduce chiller energy consumption. The external air passes through one or more sets of filters to catch particulates that might harm the hardware. It is also conditioned to an appropriate relative humidity.

Optimizing such a cooling system in an integrated way involves minimizing the net cost of power while ensuring that cooling requirements for a given IT load are met. This often results in a complex demand-response problem that involves inputs of weather forecast, energy prices and load-versus-efficiency curves for all the equipment involved. An integrated cooling approach involving only economizer integration, along with model predictive control strategies for temperature control, has been shown to reduce cooling management costs by up to 30 percent [6]. This situation could be further improved by the use of additional storage and demand-response management to exploit energy price variation.

A modular approach
Modular cooling units allow data centers to expand their capacities incrementally. So popular have such units become that they now constitute a de facto design standard. However, they present a challenge to integrated cooling control as there is an interaction between them and related common facilities such as the chiller, evaporator and economizer. This poses additional constraints on the integrated cooling control problem described above.

ABB's cpmPlus Energy Manager has the ability to handle such integrated demand response management problems to help customers realize additional benefits.

Optimizing a cooling system in an integrated way involves minimizing the net cost of power while ensuring that cooling IT requirements are met. This often results in a complex demand response problem.

3 Drivers for novel cooling design and representative cases

Driver	Representative cases	Comments
Thermodynamic efficiency	Aisle containment On-chip cooling	Efforts targeted toward minimizing energy and exergy loss by localized heat removal and avoidance of mixing different temperature streams.
Materials	Liquid cooling Membrane air drying and cooling	Novel materials are offering higher efficiency and more rapid heat removal.
Waste heat recovery	Absorption cooling	Cooling with waste heat recovered from data centers is one of the most promising options.
Renewable integration	Solar cooling	Solar cooling is one of the most promising options for using renewables for data center cooling.

Integrated management of power, IT and cooling

In almost all existing data centers the IT load management is not coupled with the cooling management or the power supply. That means the IT load management software makes an independent decision when to start new IT jobs, or when to migrate running jobs, without any consideration for the cooling or power required. This "selfish" behavior can reduce the power used by the IT equipment, but at the expense of a higher cooling energy consumption.

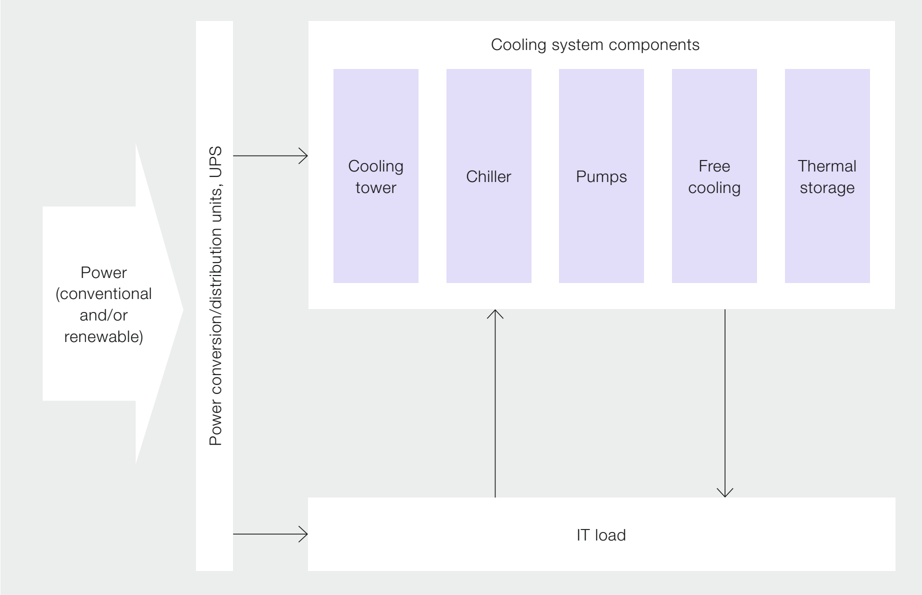
To avoid such scenarios, coordination of all three subsystems is required. Furthermore, it is also necessary to have a dynamic and predictive IT load management tool so that the data center location and corresponding time-varying energy provisioning can be taken into account. Such an advanced load management, which could be integrated with ABB's data center infrastructure management (DCIM) system, Decathlon™, can lead to energy savings of 20 to 40 percent [7].

Such a solution can also directly accommodate maintenance aspects – for example, by load sharing among servers and their related cooling devices to equalize component aging. It can help with power management too: Should cooling requirements or energy prices reach critical values, Decathlon, for example, can dynamically lower the voltage supplied to components or reduce the clock frequency to reduce cooling needs and energy consumption. This technique, called dynamic voltage and frequency scaling (DVFS), is performed in such a way so as to ensure IT jobs do not violate their given service level agreements (SLAs). IT jobs can be migrated to other servers, too, to save power or cooling. In the past, such migration was limited to a very few applications that supported check-pointing, but increased use of virtualized servers now makes migration easier.

Coordinated management can be extended to incorporate resources not just from one data center but from several, geographically distributed data centers. This can lead to further energy savings of 5 to 10 percent. The main advantage of spreading IT loads between data centers is that the installed capacity per data center can be smaller than the maximum that would be needed were the data center to operate in isolation, as some resources can be shared. This indirectly also leads to a better energy usage. An IT load-sharing strategy exploits time-of-day energy price variations and ambient temperature differences between locations. Energy price predictions and cooling forecasts can easily be extracted from Decathlon, leaving only the information flow to the IT load management to be established.

IT load management across data centers provides benefits but is also subject to legal and logistical constraints. For example, data may be bound to a certain jurisdiction, thus limiting migration options. In addition, security aspects and data pro-

4 Schematic of data center showing cooling, IT and power components



tection become important if the data centers belong to different legal entities. Furthermore, the additional energy demand and communication costs involved in migration must be considered.

Reliability

Fluctuating humidity, poor air quality and temperature variations are the main phenomena related to the use of an economizer that impact reliability. To improve reliability, the intake air quality can be monitored and if it drops below certain standards preventive actions can be taken. For example, Decathlon can automatically close external air intake vents and switch to another means of cooling when air quality standards are threatened.

Hot spots also detrimentally affect reliability. Effective monitoring and control can deal with these without overprovision of cooling for the entire data center. This directly reduces energy costs.

Another approach used to increase reliability is to regularly maintain or replace critical equipment before failure occurs. The intervention can occur after a fixed period defined by the mean time between failures or the manufacturer's warranty. However, a fixed period approach is not ideal. Load profiles, and environmental and operating conditions, might vary from the average values indicated by the manufacturer so it is better to tailor maintenance and replacement for each piece of equipment individually. A loss of performance or unusual equipment behavior can indicate upcoming failures, so monitoring the operating conditions of critical components can allow better planning of maintenance and replacement actions.

For example, the voltages across several capacitors of a power converter show massive voltage drops and unusual oscillations shortly before the power adapter fails. If such deviations are monitored and automatically tracked, preventive actions like repair or replacement can be initiated just when they are needed. Equipment downtime is thus decreased as failures are predicted and corrected before equipment drops out. Consequently, reliability and availability of the data center are increased. In addition, unnecessary maintenance and replacement costs are eliminated.

ABB has demonstrated its capability to monitor and ensure system reliability in a wide range of mission-critical applications in industrial power and automation settings. This experience puts ABB in a perfect position to manage mission-critical data centers for customers, especially when tools like Decathlon are available.

Advanced load management, which could be integrated with ABB's Decathlon DCIM system, can lead to energy savings of 20 to 40 percent.

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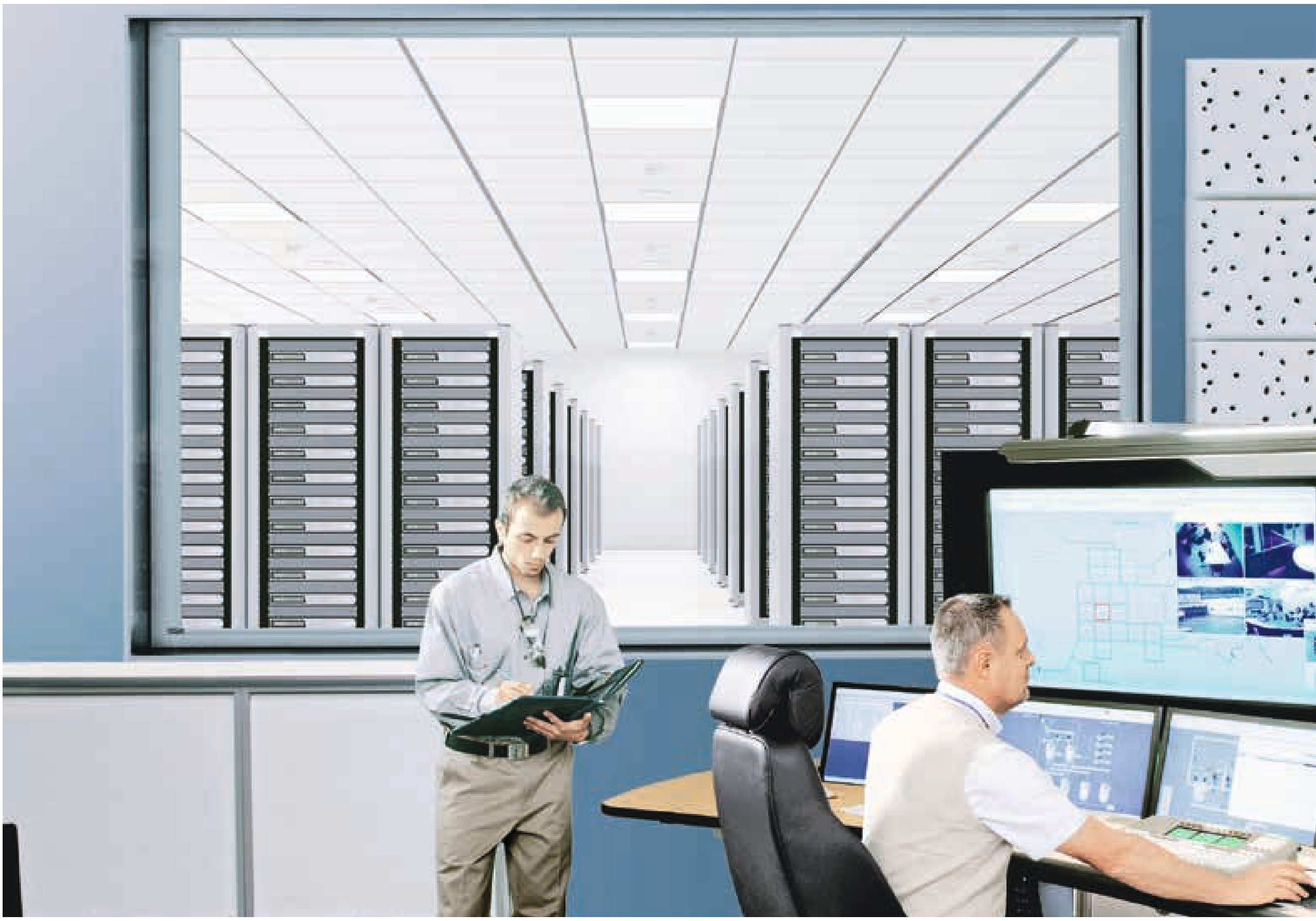


In the crystal ball

Looking ahead at data center design optimization

ZHENYUAN WANG, ALEXANDRE OUDALOV, FRANCISCO CANALES, ERNST SCHOLTZ – “Data center design optimization” is a phrase that rolls easily off the tongue, but actually optimizing the design of a data center is a good deal more difficult than it sounds because the owners, architects and engineers who have a say in the design may all have different priorities. The ability to reconcile the desires of these parties as well as accommodate current and future trends in the industry is a core skill in the art of data center optimization. Energy efficiency is one particularly significant and dynamic trend, and the DC-only, energy self-sufficient feature is one aspect of this trend that is attracting major attention worldwide.

For data centers, a DC-only world would be perfect, especially as DC is native to most renewable energy sources.

Conventional power generators are usually alternating current (AC) based and between the generator and the direct current (DC) electronic loads in, say, a data center, there can be many wasteful AC/DC/AC/DC conversion stages. A DC-only world would be perfect, especially as DC is native to most renewable energy sources. This DC vision has inspired, for example, the DC microgrid-enabled "enernet" ideas of the EMerge Alliance – a not-for-profit, open industry association that is promoting the rapid adoption of safe DC power distribution in commercial buildings through the development of appropriate standards [1]. By reducing the number of AC/DC conversion stages in typical AC-powered electronics, a DC building can be typically five to fifteen percent more efficient. Further, by producing electrical energy locally from biofuel, solar photovoltaic (PV) and wind sources, zero-net-energy buildings (ZEBs) can become a self-sufficient alternative to conventional, externally powered buildings. Data centers are a major application area of this vision.

Title picture
Server performance is just one of many factors to be considered when designing a data center.

Other considerations

For data center optimization, however, there are considerations other than energy efficiency.

Capex and opex

Many factors impact the ultimate cost of a particular architecture – for example, mitigating harmonic currents injected to the AC network may require filtering equipment to be inserted between the utility grid and the data center, thus increasing capex.

Reliability and availability

Conventional AC data center designs are classified into different tiers and each tier has its own reliability and availability requirements (see pages 11–15 of this edition of *ABB Review*). Apart from public image damage, outages can also have a huge financial impact on a data center owner/operator. A self-healing function in the power supply network can improve reliability and this is becoming increasingly popular in data centers. On the other hand, reliability and availability improvement often incurs more cost.

Protection and safety

Appropriate protection and safety measures have to be rigorously implemented.

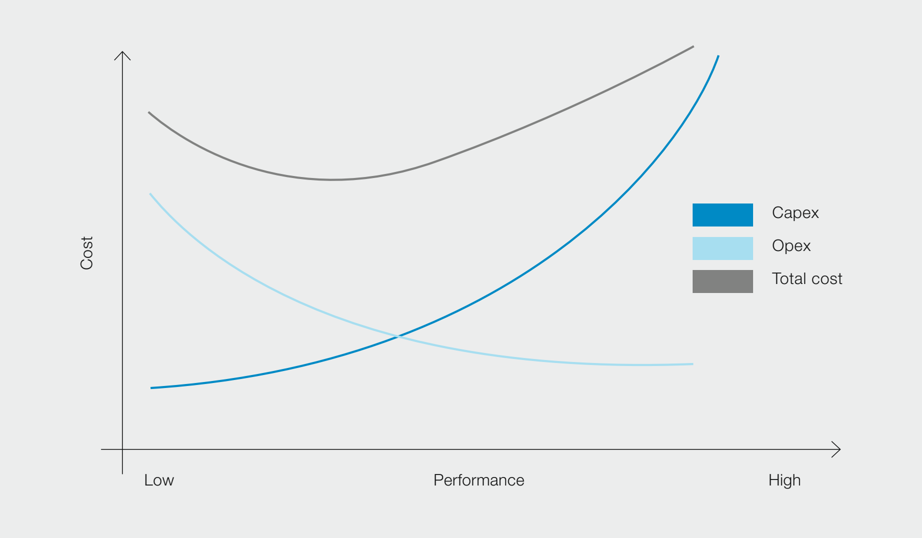
Scalability

To meet growing requirements, some data center owners plan to incrementally expand server capability and power capacity. The latter may involve backup generator type and number considerations, modular UPS converter/battery configuration, etc.

Footprint

A smaller footprint is advantageous where real estate is costly. However, this necessitates higher power density in server racks, UPS converters, etc. and translates into higher cooling system costs.

1 Finding the minimum TCO for a single performance target (eg, reliability, efficiency, environment impact)



By producing electrical energy locally from biofuel, photovoltaic and wind sources, zero-net-energy buildings can become a self-sufficient alternative to conventional, externally-powered buildings.

Renewables
Renewable energy sources, especially PV and wind, should be easily accommodated. Use of renewables polishes the data center's public image and additional capex can often be recouped in renewable-resource-rich locations. Globally, the "green" data center is a growing trend.

Zero-net-energy (ZNE)
ZNE data centers are usually smaller than average and often have access to renewable energy resources. A reliable utility backup and service agreement as well as energy storage will be needed in most cases.

Cooling
Modern data centers have rack power densities over 10 kW/rack and this will continue to increase. Liquid cooling applies over 20 kW/rack – this will translate into higher initial capex.

Location
The geographical location of the data center is a consideration when there are multiple options. The location impacts the real estate cost, cost of electricity, the initial and operating cost of cooling, etc.

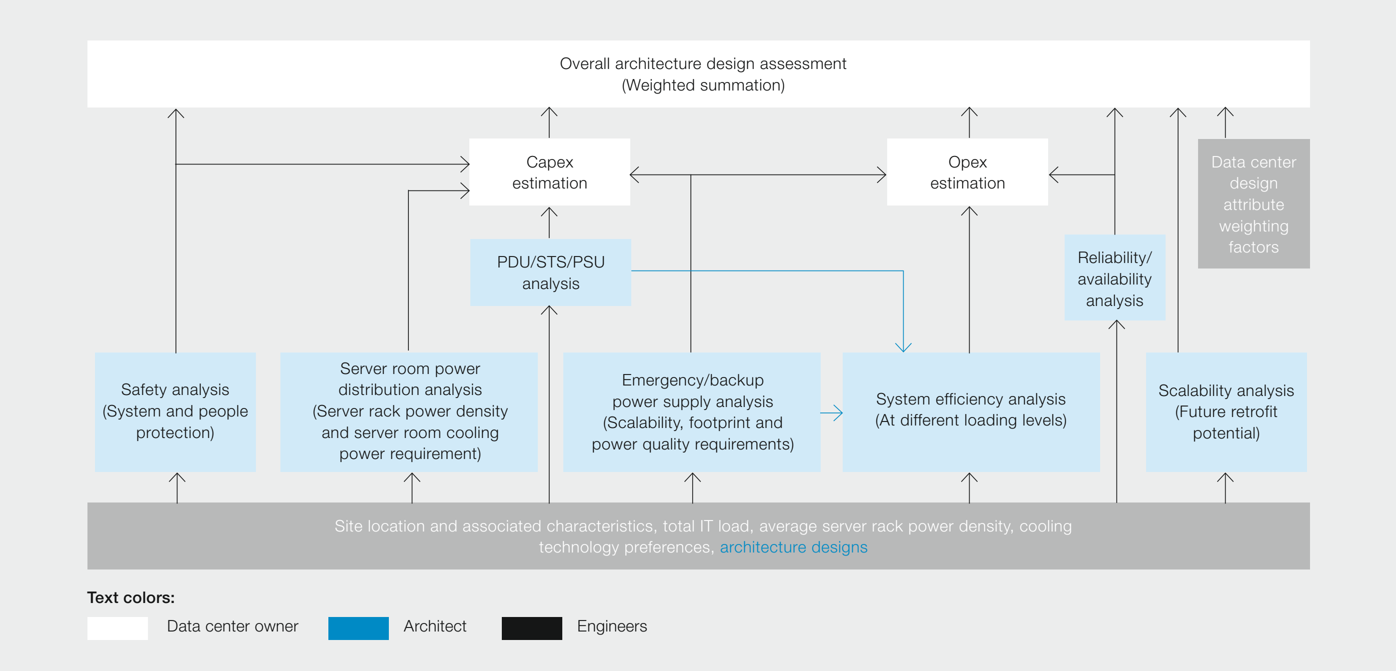
The question is: Given so many interconnected factors affecting the final architecture decision, how can one determine an optimal architecture?

Is an optimal design even possible?

The definition of an "optimal design" is important. For some, it is the design that gives the minimum total cost of ownership (TCO) for a given performance target → 1. For others, it is the one with the least environmental impact, or with the smallest footprint, or the highest efficiency, and so on. For a greenfield developer with a strong sense of environmental responsibility and a strong capital position, "optimal" would most likely mean "greenest"; for a small developer who wants a quick return on investment, the smallest initial capex may be his "optimal" and he may not be interested in costly renewable technologies now.

An optimal data center architecture design is always possible for a given data center developer with clear objectives in mind. But some fundamental assumptions and requirements must be discussed:
- The number of years the data center should function before a major makeover.
- The geographical location of the intended data center, as this determines the cost of real estate and energy, alternative energy supply potential, weather (cooling costs) and factors such as contracts with utilities to provide ancillary services, or with other building owners to provide centralized heating services (this can help to offset expenses).
- Average server rack power density for the planned functional lifetime of the data center.
- The reliability and availability targets or, alternatively, the annual outage penalty that can be tolerated.

2 Data center architecture design optimization process. Arrows show dependencies; engineering analysis items are in the light blue blocks.



– Site constraints (available space, utility supplies and connection requirements).
– Long-term plan for the site and the data center.

Given the definition of “optimal” and the fundamental assumptions and requirements, multiple data center architecture designs can be developed and analyzed to determine the best candidate. This process, however, requires the involvement of all parties: the owner, the architect and the engineers (for IT, network, electrical, cooling, etc.) ➔ 2.

The data center owner’s role

The data center owner (or recipient of the optimized architecture solution) plays a pivotal role in the optimization process as he is well acquainted with many aspects relevant to the data center design. These include but are not limited to:

– The geographical location, with the associated information mentioned above.
– Planned load capacity (in MW) in the short-term and in the future. This impacts the oversizing and reliability considerations of the power equipment.
– Average server rack power density (kW/rack). This will influence the cooling system design and the dimensioning of the power equipment.
– Preferred cooling technologies.

Most importantly, the owner gives major input to the process due to the fact that it is he who will weight the different attributes in the overall assessment.

The architect’s role

Based on the owner’s inputs, the data center architect will come up with several designs. These designs can be based on DC, conventional AC or a mixture of the two. A design can also incorporate multiple emergency/backup energy sources, protection schemes, etc. In principle, the architecture will roughly determine the cost and performance attributes of a data center – more exact figures will be determined later by rigorous engineering calculations and evaluations.

The engineer’s role

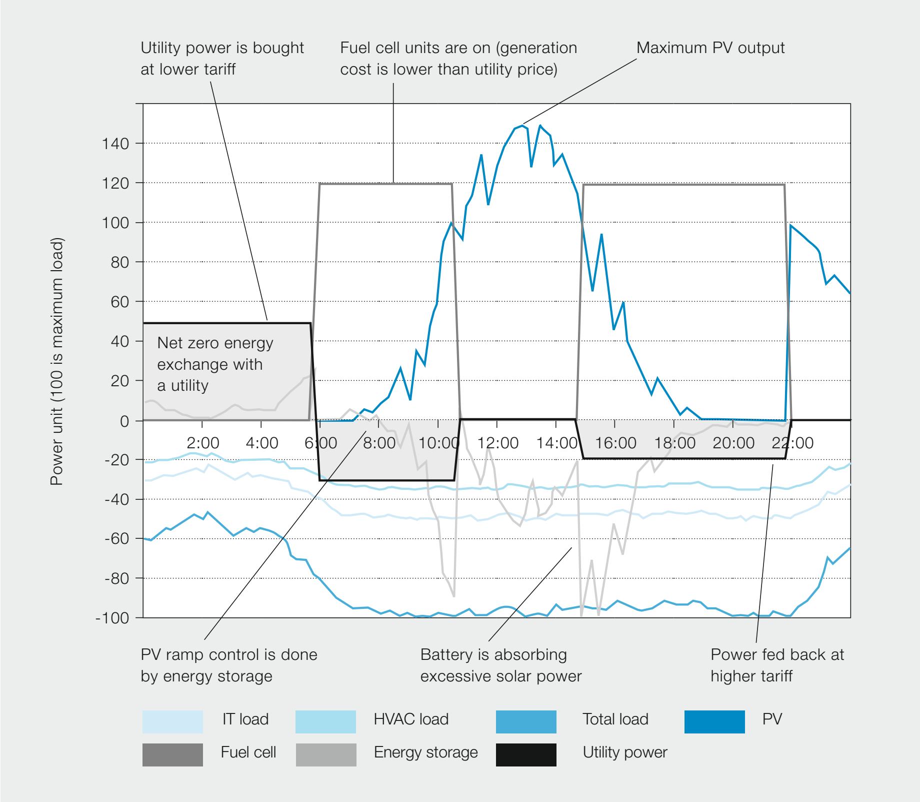
Engineering analysis takes center stage after the owner’s requirements and the architecture have been clarified. Provision of the power supply alone involves numerous analyses ➔ 2:

– Power distribution unit (PDU), static transfer switch (STS) and power supply unit (PSU) analysis. Depending on the architecture and total IT load, the type, rating, footprint, power density, efficiency, reliability, cost and number required must be determined.
– Server room power distribution analysis. Depending on the server rack power density and the selected cooling technology, this analysis

Scalability is important as, to meet growing requirements, some data center owners plan to incrementally expand server capability and power capacity.

Cost minimization and energy efficiency maximization can be treated as the two most important data center design objectives – reliability is a given requirement and cannot be compromised.

3 A ZNE data center must consume no net energy from the utility grid over a specified time period.



determines the size, length and safety grounding for the power distribution bus and feeder.

– Emergency/backup power supply analysis. Emergency power supply refers to uninterruptable power supply (UPS) systems, which can be based on batteries, ultracapacitors or flywheels; backup power supply refers to diesel generator sets or other types of generation devices that can provide power for hours to days. The architect may have considered the type and redundancy, but this analysis details the ratings, auxiliaries (protection and control), footprint, efficiency, reliability, cost and number of these power supplies. Construction cost differences between alternative technologies are considered in the layout of the emergency/backup power supply rooms (eg, converter/battery rooms).

Multiple data center architecture designs can be developed and analyzed to determine the best candidate.

– Safety analysis determines appropriate protection devices and grounding practices – including the type, rating and number of the protection devices, and the size/length of the grounding conductors. The fault-current limiting function of converters is considered in the protection device dimensioning.

– System efficiency analysis will be done for at least three loading levels: 20, 50 and 100 percent. Efficiency curves of PDU/STS/PSU and UPS converters are the main inputs to this analysis. Server room distribution feeders are quite short and their efficiency can be assumed to be 100 percent, when they are considered.

– The system efficiency analysis result is the major input for the opex estimation, as are data center emergency/backup operation cost and outage revenue loss or penalty. Capex is estimated based on data center IT power supply/distribution equipment and protection equipment costs. Other types of opex and capex

are considered to be the same for all architecture designs and are not considered in the optimization process.
- Reliability/availability analysis is important to ensure the architecture meets certain requirements [2]. A DC data center design may be on a par with a higher-tier AC design in this respect due to savings in power conversion stages.
- Scalability analysis looks at potential power equipment modularity and hot-swapping benefits, or the integrated data center.

Overall architecture design assessment

The overall assessment is usually straightforward – it can be a simple weighted sum calculation. However, as explained earlier, the data center owner bears the ultimate responsibility in assigning ranking weights to different design attributes.

Trends

In general, cost minimization (both capex and opex) and energy efficiency maximization can be treated as the two most important data center design objectives (reliability is a given requirement and cannot be compromised). In addition, data center design optimization has to consider the major industry trends:
- Greener: Designs using renewable or reduced carbon energy resources are of growing interest. A zero net energy (ZNE) data center is a goal.
- Modular: Data centers can be quickly constructed and maintained by using standardized and plug-and-play-capable server racks, power modules, battery packs, cooling equipment and generator modules.
- Cloudier: Economies of scale can be exploited by colocating the IT services of several organizations, especially cloud service providers, in one data center.
- Hotter: With the advent of blade servers, the power density of server racks has increased significantly, posing cooling challenges.

Further, the ZNE building concept is attracting interest due to several drivers [3] that are also relevant to data centers:
- Rapid price drop of local generation technologies (mainly PV panels)
- Controllable loads – heating, ventilation, air conditioning and lighting; the IT load can be shifted, especially in cloud computing data centers
- Progress in energy-efficient building construction technologies (in the case of data centers, more efficient architectures, too)

By definition, a ZNE data center must consume no net energy from the utility grid over a specified time period → 3. Since data centers are characterized by a very high consumption density (100 times that of an average office building) with relatively low daily/seasonal variation, several key factors must be considered in ZNE data center architecture designs:
- Availability of energy supply for local generation
- Type, operation mode and size of local generation
- IT load balancing
- Near-term IT load and local generation forecasting

The design can be AC or DC. However, a DC design will be more efficient, making it easier to achieve ZNE operation.

For fuel-cell and PV-powered ZNE data centers, microgrid operation, ie, self-powered and isolated from the grid, is a real possibility. However, design optimization to accommodate microgrid operation as well as all the other requirements mentioned above is a whole other story.

The owner gives major input to the process due to the fact that it is he who will weight the different attributes in the overall assessment.

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Taking charge

Flash charging is just the ticket for clean transportation

BRUCE WARNER, OLIVIER AUGÉ, ANDREAS MOGLESTUE – If you thought that charging electric vehicles was all about fiddling with charger cables followed by long and unproductive waits, then think again. ABB has (together with partners) developed an electric bus that not only automatically charges in 15 s, but also provides high transportation capacity and energy efficiency. The bus connects to an overhead high-power charging contact when it pulls into a stop and tops up its batteries during the time its passengers are embarking and disembarking. Besides being an attractive means of transportation, the TOSA bus that is presently running in the Swiss city of Geneva also has numerous environmental bonuses. It is silent, entirely emissions free, uses long-life and small batteries while the visual clutter of overhead lines and pylons that is often a barrier to trolleybus acceptance is made a thing of the past. The system is inherently safe because the overhead connectors are only energized when they are engaged, and the electromagnetic fields associated with inductive charging concepts are avoided. Such has been the success of the demonstrator that the concept is now being developed for series production. Let the future begin.

Title picture
The TOSA demonstration bus is presently running in public service in Geneva.

The world is becoming increasingly urban. In 2008, for the first time in the history of humanity, more than half the planet's population lived in cities. Cities bring with them many challenges, not least of which is the efficient organization of transportation. To avert gridlock and reduce pollution, planners across the globe are encouraging the use of public transportation.

Public transportation in cities can take numerous forms, but what they all have in common is that they require energy to be transmitted from a fixed supply to a moving vehicle. Some particular solutions aside, this transmission takes one of two forms: Power is either stored on the vehicle (usually in the form of diesel fuel, as on a bus) or transmitted electrically (requiring a continuous contact system as on metros, trams and trolleybuses). The latter forms of transportation are typically seen on heavily used corridors where the significant infrastructural investment is easier to justify. The former solution is typical for more lightly patronized corridors where lower startup costs permit routes to be created or modified more flexibly.

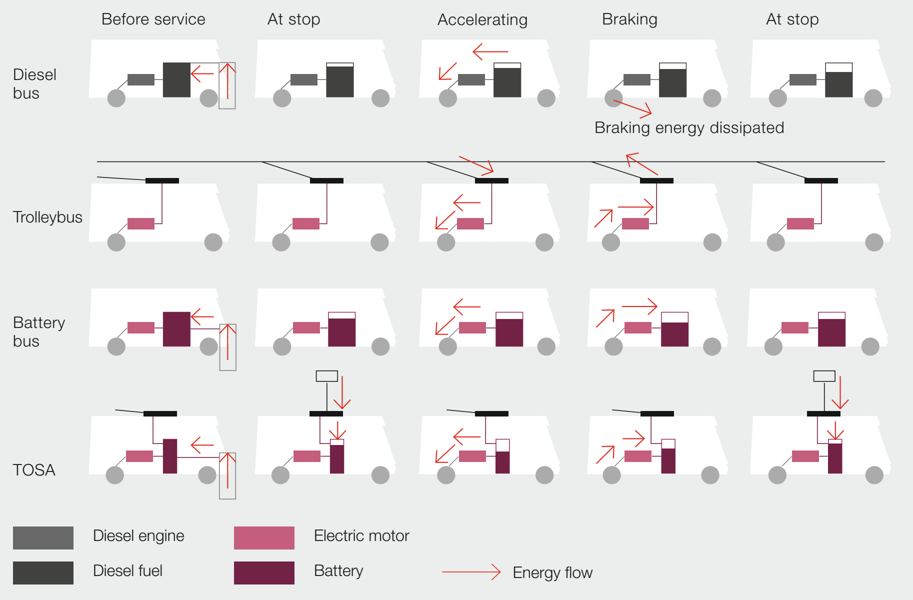
This status quo has held its own for many decades, but how much longer can it do so? Rising fuel prices and the reduced acceptability of noise and pollution have led manufacturers and operators to think about alternatives to diesel for powering buses ➔ 1. Solutions implemented to varying degrees include less conventional fuels (such as natural gas) and adopting alternative propulsion concepts, for example hybrid buses, battery buses and trolleybuses. A feature shared by the latter three is that they use electric motors, permitting energy to be recovered when the bus brakes, creating an opportunity to reduce energy wastage. Recovering energy is not, however,

Recovering energy when the bus brakes helps reduce wastage.

1 Signs of change

- The International Energy Agency predicts that oil prices will remain above $100 / barrel in the foreseeable future.
- A McKinsey study predicts the price of Li-Ion batteries for cars will fall by almost 75 percent (from present level) by 2025.
- Carbon duties are being introduced across the world and will rise further.
- There is global pressure to reduce emissions from road transportation (eg, EURO 6 emissions standards)
- Progress in power electronics (higher switching frequencies, lower losses, more compact converters) are increasing the viability of all-electric solutions.

2 Comparison of modes of operation



3 Alternatives to overhead lines

The idea of seeking to transmit power to vehicles by means other than overhead lines is far from new. In the early part of the 20th century, some tram systems used a so-called "conduit", in which a conductor was embedded in a narrow groove in the road. However, the groove was vulnerable to blockage by debris, while the risk of electric shock to other road users could not be excluded. Several manufacturers have revisited the idea in recent years, with the conduit being replaced by a safer and more sophisticated contact – or induction-based transmission. These can be combined with batteries avoiding the need to embed the costly equipment along the full route. The induction-based version can also be used to recharge other road vehicles, including buses. However, the system retains several disadvantages, including energy losses during charging and the high cost of burying the charging infrastructure.

ABB's flash charging system is inherently safe because the charging points are only energized when the bus is actually connected ➔ 5. Because it uses a direct electrical connection, concerns over electromagnetic fields can be mitigated. Furthermore, not requiring the installation of heavy equipment under the roadway simplifies the installation process and reduces the associated disruption.

strictly the same as re-using it. Hybrid and battery vehicles use batteries to bridge the mismatch between supply and demand, whereas in the case of trolleybuses this can be handled by the substations and grid ➔ 2.

Battery buses have limitations. Despite considerable progress in battery technology, their energy density is orders of magnitude lower than that of diesel fuel[1]. The extra weight that batteries add to the bus reflects negatively on its energy footprint, and the space they require can reduce passenger-carrying capacity. This can be countered by using fewer batteries (and recharging them more often) but such additional visits to the charging station have a time and productivity penalty.

The trolleybus trumps these disadvantages. The absence of a larger on-board energy storage system reduces vehicle weight and permits better acceleration using less energy. The disadvantage, however, lies (or rather hangs) in the overhead lines. These are costly to install and maintain and are not always welcome due to their visual impact ➔ 3.

Is there a way to keep a battery bus on the road without resorting to either large, heavy and space-consuming energy storage or to frequently having to take the bus out of service for a deep and full recharge?

Footnote

1 Diesel fuel has an energy density of about 46 MJ/kg, whereas rechargeable batteries still have less than 1 MJ/kg.

4 Partners in the TOSA project

The following four companies initiated the TOSA project:
– TPG, Geneva's public transportation operator
– OPI, Lake Geneva area office for the promotion of industry
– SIG, Geneva's utility
– ABB (ABB Sécheron Ltd.)

(hence the name TOSA, which also stands for "trolleybus optimisation système alimentation" or optimized charging system for trolleybus)

Further partners of the project include:
– Palexpo (trade fair center) and Geneva airport
– Hepia (University of applied science), architecture design of the bus stops
– HESS, manufacturer of the bus
– Canton of Geneva, Federal Office for Energy, Federal Office for Highways
– EPFL and HeArc Universities

Overhead lines for trolleybuses are costly to install and maintain and are not always welcome due to their visual impact

5 The bus recharges at stops using its roof-mounted contacts that engage using laser guidance.

Transport passengers not batteries

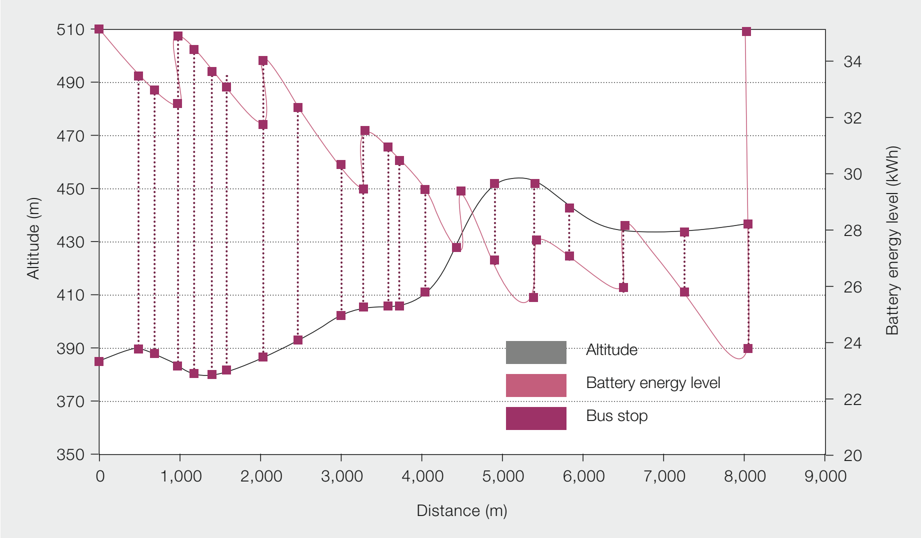
One fundamental difference between buses and automobiles is that buses follow fixed routes. The question of "range of operation" which is of significance to electric cars is reduced to the more manageable "distance to next recharging opportunity" for a bus. With buses predictably stopping at regular intervals, charging points can be located at the stops. With the bus being able to top up its charge at these points, the need for large and heavy batteries is avoided and the vehicle becomes lighter, more agile, more energy efficient as well as providing more space for passengers inside. Furthermore, if charging time can be limited to the time that the bus needs to stop anyway, negative effects on the schedule can be avoided. Together with partners ➔ 4, ABB has created the TOSA bus to present a solution based on this approach.

Flash charging and smart grid

The high-power (400 kW, 15 s) charging of the high-power density batteries on the bus can result in load peaks affecting the local grid. The flash charger station, however, flattens out the demand by charging super capacitors over a period of a few minutes while drawing a lower current from the grid. As this current is up to 10 times less than would be the case without storage, the connection can be made with a cheaper and more readily available low-power supply. Additionally, recharging of the supercapacitors is timed so that they are left discharged for longer periods when the bus service is running at lower frequency. As supercapacitors are aged by higher voltages this "smart" functionality allows the life of the supercaptitors to be doubled.

The TOSA demonstrator bus will be running in public service on a short line in Geneva, Switzerland until April 2014.

6 Short top-up charges help maintain the battery level.



With limited time being available at stops (passengers typically embark and disembark in 15 to 25 s), as little time as possible should be lost in establishing the electrical connection. The electrical connection is established in under a second. As the bus approaches a stop it is the driver's responsibility to oversee the safety of the passengers and pedestrians and keep an eye on surrounding traffic. To avoid placing additional demands on the driver, the connection system is automatic. A laser aligns the moving equipment on the bus roof with the static overhead receptacle ➔ 5. The connection is made as soon as the brakes are applied.

The bus draws a 400 kW charge for 15 seconds while at a stop.

By virtue of the receptacle's height above the road surface, and furthermore by being energized only when a bus is present, this is an inherently safe solution.

The timetable defines the service and the economics

Operating costs for a bus service are highly dependent on driver wages, schedule frequency and fleet size. Therefore, the change from diesel to electric supply should not reduce the commercial average speed nor require an increase of the fleet size to provide the same service.

It was this requirement that led to the creation of two types of feeding stations along the route: The flash station and the terminal station. As described, the flash stations provide a short high power boost of energy. However, drawing 400 kW for 15 s is not sufficient to fully recharge the batteries ➔ 6. More prolonged charges of three to five minutes at 200 kW are thus delivered at the terminus where buses are scheduled to stop for longer periods (in order to permit the driver to take a break and to provide some recovery buffer in case the bus is running late). The time required for recharging at the terminus should thus not risk causing the bus to fall behind its schedule or to be unable to catch up when it running late.

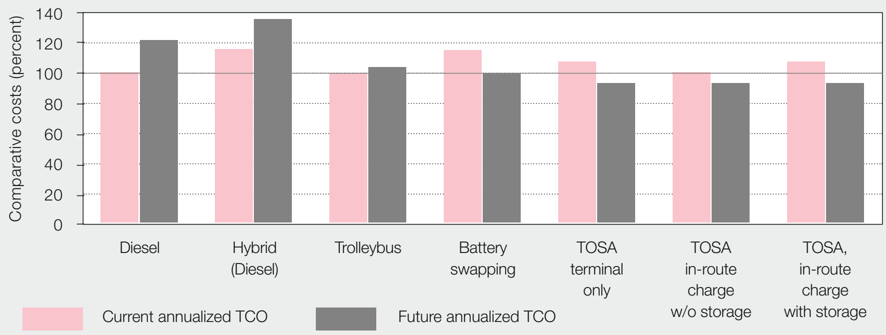
The terminal charger consists of a simple 12 pole diode rectifier. This converts the incoming AC supply to DC in a similar way as is done for DC railways, trams or trolleybuses. The voltage used in this case is 500 V. This solution is simple and cost effective as well as being extremely reliable.

The flash charger has a more complicated but more flexible power electronic configuration. It uses a controlled rectifier to charge the supercapacitors. This is able to regulate the amount of charging current. When the bus connects the controller closes a contact on the output

7 The technology will be introduced on a full-length bus route in Geneva.

- 11 articulated buses (18 m)
- Two powered axles (out of three)
- Batteries per bus equivalent to circa two electric cars (38 kWh)
- Every bus has capacity for 134 passengers
- Charging draws energy from 400 VAC low-voltage network

8 Flash charging is already a competitive solution. Its competitiveness will increase further in the future.



Costs shown exclude costs common to all modes (such as the driver).

side of the supercapacitors to discharge them into the bus.

During operation, the batteries receive further top-up charges as the bus brakes. Rather than using a friction-based system that converts all the kinetic energy to heat, the bus' motors can switch to generator mode and return much of this energy to the batteries ➔ 2.

The battery charge for a typical trip is mapped in ➔ 6. The graph shows how the batteries are topped up at stops but a far larger charge is received at the terminus stop.

The TOSA bus is inherently suitable for using renewable energy.

There is a third type of charger, for the depot, where a longer charge is applied to compensate the energy required between the operating line and depot location. As there is more time for charging at the depot a flash charging station is not required. The bus is plugged into a dedicated supply using a cable. A total of four buses can be connected to a depot charger which charges them sequentially. The electrical configuration is the same as that of the terminal, a 12-pulse diode rectifier, however the power rating of the depot is 50 kW as opposed to the 200 kW of the terminal.

Renewable energy

The TOSA bus is inherently suitable for using renewable energy. In contrast to classical electric vehicles, which typically recharge when they arrive home in the evening, the bus recharges during the day and can thus make direct use of solar energy as it is produced. The ability of flash charging stations to store energy for short periods and flatten out charging peaks can also protect the system against short-term fluctuations in solar generation.

Demonstration in Geneva

The TOSA demonstrator bus is currently running in public service on a short line in the Geneva, Switzerland (between the airport and the convention center PALEXPO). The demonstration will continue until April 2014. The bus has so far performed flawlessly. As a next step, the technology will be introduced on a full-length bus line in Geneva ➔ 7.

A competitive solution

ABB's flash charging system for buses is already competitive today, and will become even more competitive in the future. An economic comparison of flash charging to other modes is shown in ➔ 8. The future scenario predicted is based on assumptions of rising fuel costs and CO_2 duties and the diminishing costs of batteries.

With diesel buses becoming increasingly less attractive, both financially and from and emissions point of view, and operators seeking an attractive modern form of transportation without having to hang wires in the street, flash charging is well situated to replace both existing trolleybus routes and urban diesel routes.

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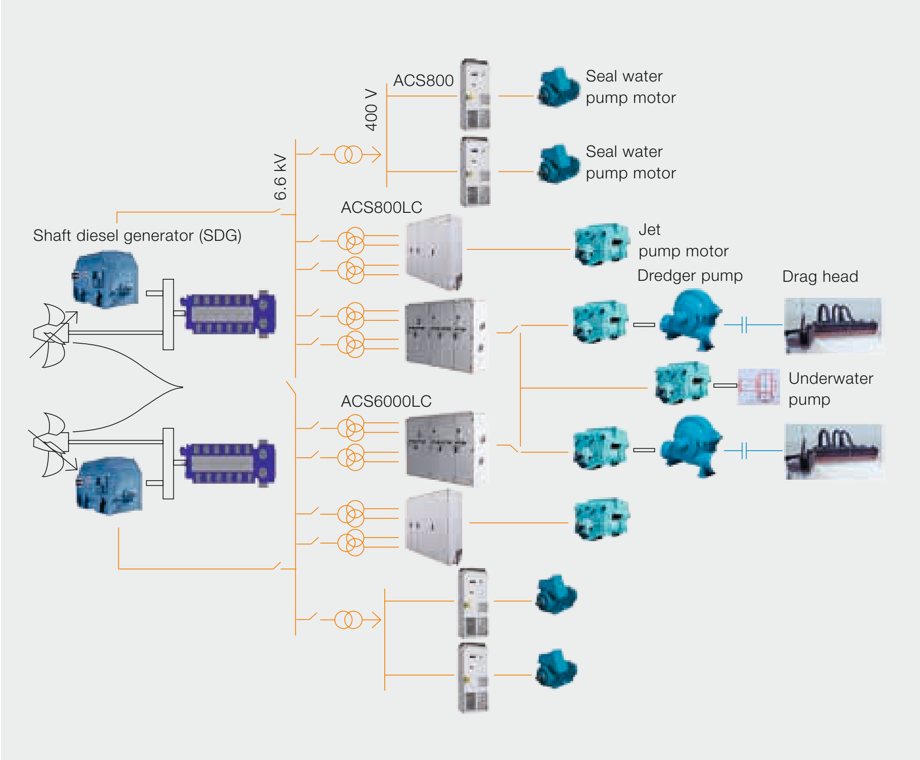
In control

ABB's dredger drives control unit provides a more reliable and integrated control platform for dredging motor systems

DAVID-BINGHUI LI, EVAN-FEI E, VISTA-HAO FENG, WEIWEI LONG – Programmable logic controllers (PLCs) are the backbone of automating electromechanical processes. Designed for multiple I/O arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact, they are well adapted to a wide range of automation tasks. Almost any production line, process or machine function can be greatly enhanced by using this type of control. ABB has taken its own PLC system to a new level, having developed an advanced PLC to control, protect and supervise all dredging consumers and systems working within trailing suction hopper dredger vessels. Its uniqueness lies in the fact the new dredger drive control unit (DreDCU) simultaneously controls multiple drive chains. ABB has successfully installed the unit in three vessels.

1 Typical configuration of a hopper dredger



A trailing suction hopper dredger (TSHD) has large, powerful pumps and engines that enable it to suck up sediments from the ocean or riverbeds. One or two suction pipes run from the vessel to the sediment floor. A drag head is attached to the end of the pipe and lowered to just above the sediment floor, making it possible to regulate the mixture of sand and water that it takes in. A TSHD generally stores the dredged material in its own hopper and discharges the leftover water overboard. The material can be discharged through hatches in the bottom of the ship or by pumping for land reclamation or beach nourishment.

Because a TSHD is used in a wide range of applications, and can dredge and transport material over long distances, it is often referred to as the workhorse of the dredging industry.

A typical TSHD electric drive system has a number of diesel engines running generators to supply electrical power to the main frequency convertors that drive all the relevant dredging consumers → 1.

Title picture
ABB's highly sophisticated dredger drives control unit brings significant fuel efficiency to trailing suction hopper dredgers.

These consumers include motors for the dredger mud, jet water, underwater and seal water pumps. Each drive chain includes a drive transformer, drive and motor.

Adjusting needs

Even as recently as five years ago only a few of the dredging consumers, such as the jet water pump, were controlled by a frequency convertor, with simple control and protection based on the product level. The other large dredging consumers were still driven by diesel engines with separate control systems. Therefore the drive control was simple and easily handled by the drives firmware.

The DreDCU easily handles the need for increased cooperation between different drive chains.

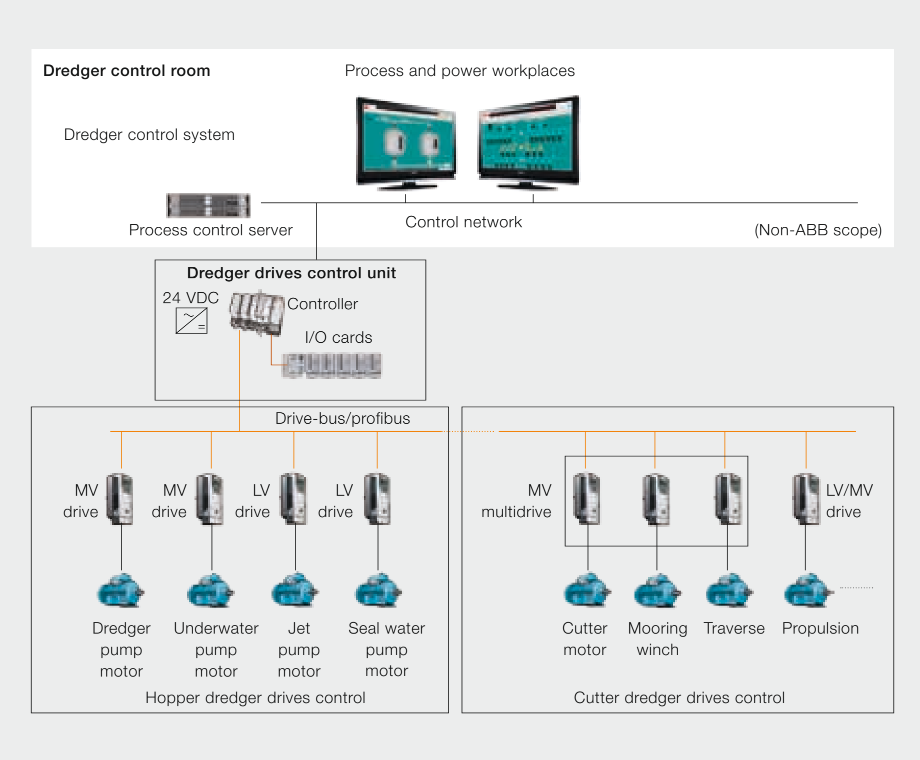
Yet it became clear that significant fuel efficiency could be gained by having further dredging consumers controlled by frequency convertors. Adding additional consumers to the drive control clearly makes the control process much more complicated. For instance, an additional changeover function between a mud pump and an underwater pump must be controlled, or a master/follower function between two dredger pumps must be overseen. However this need for increased cooperation between different drive chains and protection for each chain from the system level does not become a problem due to the sophistication of the DreDCU.

Development process

ABB already offered a sophisticated PLC unit for single-drive systems used for propulsion and thrusters. Yet in order to accommodate the complicated and multiple drives specific to dredger applications, a new control unit needed to be developed. The company utilized one of its existing controllers as a base for the DreDCU.

ABB's Extended Automation System 800xA family of controllers, communication interfaces and I/O modules have been meeting the needs of today's most sophisticated plant automation systems. The flagship controller of System

2 ABB's new dredger drive control unit



3 Main features of DreDCU

- One unit controls up to 11 drives
- Interface to remote control and integrated automation system (supports PROFIBUS and Modbus)
- Optional local panel
- Optional interface to remote diagnostics support
- Optional interface to advisory system
- Meets main class society requirements

The current DreDCU application software is a standardized and scalable software package based partly on the existing software library of the AC 800M.

800xA, the AC 800M, is a modular process PLC with communication functions as well as full redundancy and support for a large range of I/O systems. It can integrate various networks, fieldbuses, serial protocols and I/Os, providing seamless execution of advanced and unhindered process control strategies as well as functional safety, electrical, quality control, and power management applications. It can deliver automation solutions for small and large applications.

The DreDCU is made up of an AC 800M hardware platform with embedded application software, communication modules and modems, I/O modules and power supplies → 2. An optional local panel provides an alarm list and displays detailed information for each activated alarm.

Adding additional consumers to the drive control makes the control process much more complicated.

The hardware is located in the DreDCU cabinet (alternatively a part of the converter cabinets), which is placed in the frequency convertor room on the vessel.

As the DreDCU is designed for a specific vessel type with specific functions and relationship with ABB drives, it is available as part of an entire electric system package → 3. The multidrive control aspects have been tweaked to handle dredger applications. The current DreDCU application software is a standardized and scalable software package that is based partly on the existing software library of the AC 800M. The existing library was adjusted to shift from a propulsion application to a dredging application. A changeover function between a mud pump and an underwater pump had to be developed, special mud pump interfaces added and the start/stop procedure changed according to the dredger application. A process panel software was also developed for the mud pumps on which information for all drive chains can be checked.

The new control software is adapted to the project-specific configuration by means of parameterization due to different dredging applications. The DreDCU software offers standard control for dredger consumers such as sequence start/stop control, emergency stop and ramp accelerate. Optional control types include master/follower, duty overload running and changeover. The software monitors and protects all relevant dredger drive chains, sends alarms to an integrated automation system and implements auxiliary control for main dredger consumers. In

4 Trailing suction hopper dredgers equipped with the DreDCU

TongTu
Builder: Guangzhou WenChong shipyard
Owner: CCCC Tianjin Dredging Co. Ltd.
Designed by 708 Designed Institute,
classified by CCS, delivered in 2011

ABB scope of supply:
- 2x 10,000 kVA shaft generator
- 1x MSB (Main switchboard)
- 4x 1,150 kVA jet pump transformer
- 4x 3,450 kVA mud pump transformer
- 2x 2,000 kVA distribution transformer
- 2x 110 V / 30 A DC-UPS
- 2x ACS 6000 mud pump converter
- 2x ACS 800LC jet pump converter
- 2x ACS 800 sealed pump converter
- 2x 6,000 kW mud pump
- 2x 2,000 kW jet pump
- 1x DCU cabinet

No9 XinHaihu
Builder: Guangzhou WenChong shipyard
Owner: CCCC SDC Waterway Construction Co., Ltd.
Designed by 708 Designed Institute,
classified by CCS, delivered in 2012

ABB scope of supply:
- 2x 7,200 kVA / 1,500 rpm / 6.6 kV generators
- 2x earthing resistors
- 1x 6.6 kV / 50 HZ MV switchboard
- 2x 1,725 V / 5,200 kVA, mud pump transformers
- 2x 710 V / 1,650 kVA, jet pump transformers
- 2x 400 V / 1,600 kVA, distribution transformers
- 2x 3.3 kV ACS 1000 drive
- 2x 690 V ACS 800 drive
- 2x 4,500 kW / 1,500 rpm mud pump motors
- 2x 1,000 KW / 1,500 rpm jet pump motors
- 2x softstarters
- 2x DC UPS

No8 XinHaihu
Builder: Zhenhua Changxin shipyard
Owner: CCCC Shanghai Dredging Co., Ltd.
Designed by 708 Designed Institute,
classified by CCS, delivered in 2012

ABB scope of supply:
- 2x 7,200 kVA / 1,500 rpm / 6.6 kV generators
- 2x earthing resistors
- 1x 6.6 kV / 50 HZ MV switchboard
- 2x 1725 V / 5,200 kVA mud pump transformers
- 2x 710 V / 1,650 kVA jet pump transformers
- 2x 400 V / 1,600 kVA distribution transformers
- 2x 3.3 kV ACS 1000 drive
- 2x 690 V ACS 800 drive
- 2x 4,500 kW / 1,500 rpm mud pump motors
- 2x 1,000 kW / 1,500 rpm jet pump motors
- 2x softstarters
- 2x DC UPS

Simultaneous monitoring of the status of all dredging operation equipment allows for more efficient operations.

2012 ABB installed the unit in three vessels → 4.

Making headway

The benefits of the DreDCU solution are multifold. It increases the reliability of dredging operations by monitoring dredger consumers' conditions and harsh working environments, thus reducing the risk of downtime due to power loss. Simultaneous monitoring of the status of all dredging operation equipment allows for more efficient operations. Implementing a standard platform enables easy interfacing with other ABB products. Smaller cabinets provide flexibility for equipment location. Development continues with the next goal being to install the dredger drive control unit on a second type of dredging vessel, the cutter suction dredger. The end goal is to install the drive control unit on a wide range of special vessels including supply vessels, heavy lift vessels, crane vessels and installation support vessels.

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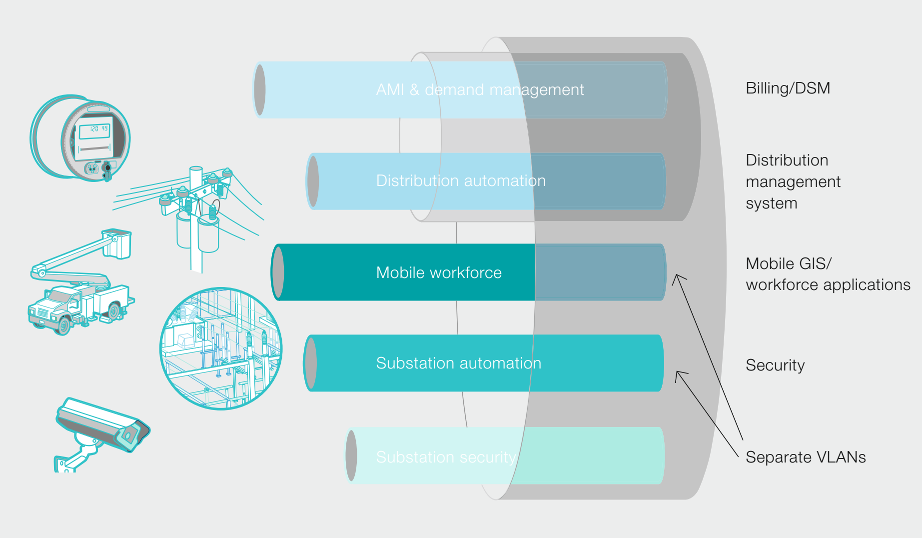
Robust radio

Meshed Wi-Fi wireless communication for industry

PETER BILL, MATHIAS KRANICH, NARASIMHA CHARI – Communication is an enabler of key applications in many sectors of industry – and wireless is often the most cost-effective and practical means of providing it. Recognizing this, ABB has extended its portfolio to include mesh 802.11 wireless technology with the acquisition of the Silicon-Valley-based company, Tropos. The Tropos mesh technology has a very robust technical foundation and is already being applied in major implementations in different industrial fields.

1 Tropos allows logical separation of the multiple applications running over the common infrastructure.



ABB's communication networks business now offers a market-leading, IP-based outdoor wireless broadband infrastructure that can be cost-effectively deployed for one or multiple applications. ABB's Tropos solution has many advantages over competing technologies [1] and is designed to deliver high broadband speed, resiliency, security and scalability. The mesh architecture is decentralized and highly flexible.

The strength of ABB's Tropos solution is founded on six cornerstones: mesh routing intelligence, radio frequency (RF) resource management, multilayer security, outdoor optimized router hardware, open standards and advanced control and analysis software.

Tropos offers a market-leading, IP-based outdoor wireless broadband infrastructure that can be cost-effectively deployed for one or multiple applications.

Title picture
Many industrial applications depend on resilient, secure and scalable wireless broadband communications. How does ABB's Tropos mesh 802.11 wireless technology provide this?

Mesh routing intelligence

By combining patented RF resource management algorithms with standards-based radio technologies operating in unlicensed frequency bands, the Tropos architecture provides a highly reliable, scalable, fault-tolerant network infrastructure that is capable of quickly and seamlessly routing around interference and congestion bottlenecks.

Unlike network architectures that are dependent on a central controller, the Tropos mesh architecture, because of its distributed networking capabilities, can easily recover from the loss of any network component. Each router continually monitors its environment for potential ways to optimize the network, so if a problem occurs with either a gateway or node router, the mesh automatically adapts its topology to keep the network up and running. When the router is brought back online, the network quickly re-establishes an optimal configuration.

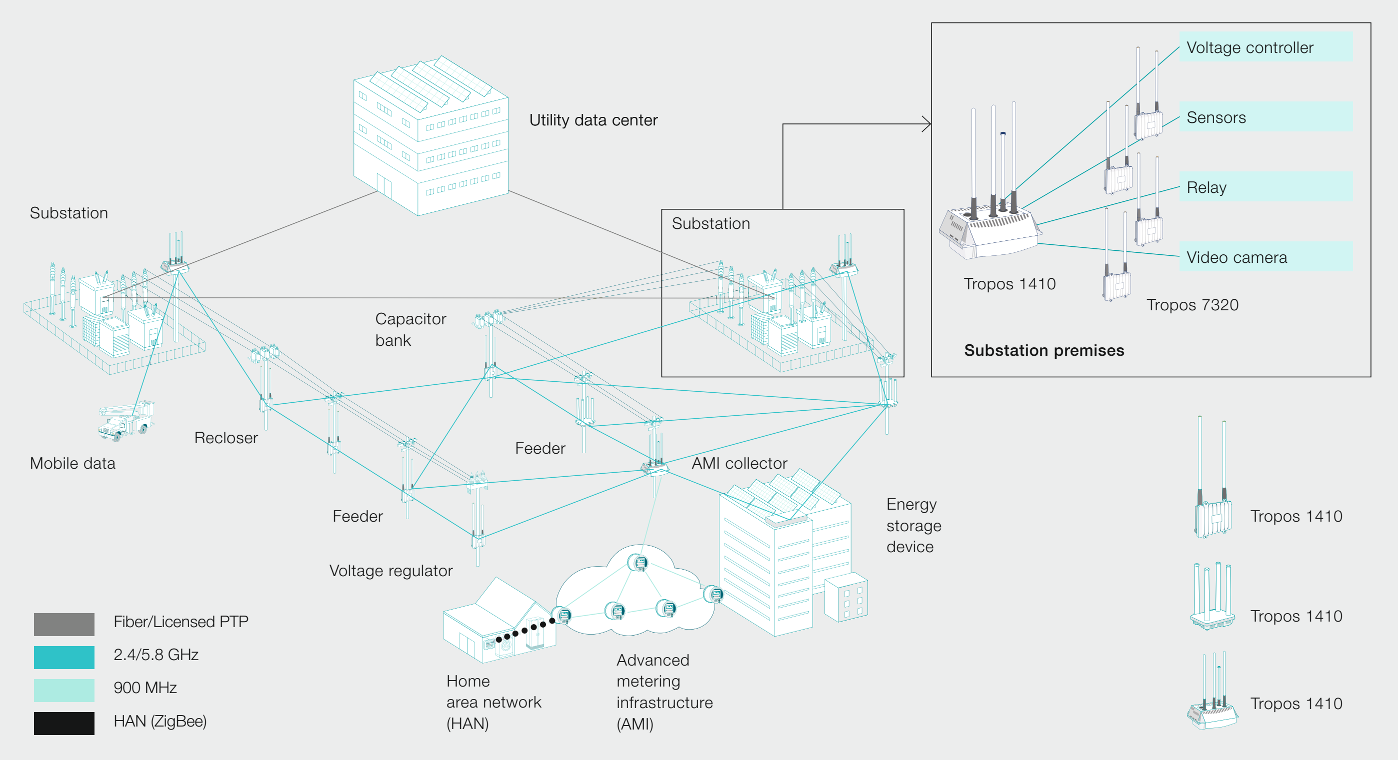
The foundation of the Tropos mesh architecture is the Predictive Wireless Routing Protocol™ (PWRP), which is based on patented routing algorithms that maximize the performance and resilience of wireless mesh networks. PWRP is a dynamic, wireless-aware routing protocol that allows mesh routers to perform end-to-end measurements of path quality and use these measurements to make routing decisions that result in the highest end-to-end throughput.

Flexible dual-radio routers

The IEEE 802.11 standard set provides support for two frequency bands of operation and Tropos is unique in enabling both radios of a dual-radio router to be used for either mesh connections or client access, thereby significantly increasing the reliability and the capacity of multi-band networks. Dual-mode routers increase mesh capacity by opportunistically exploiting less congested 4.9/5.8 GHz links whenever possible. In areas where 4.9/5.8 GHz use is restricted due to lack of line-of-sight, the routers automatically fall back to using 2.4 GHz radios, which provide a reliable long-range connection.

Seamless mobility

The fixed infrastructure Tropos mesh networks can be quickly extended with mobile routers from the same product line, for use by emergency services, for example. Each mobile node extends connectivity to client devices in the vehicle vicinity, creating a tactical response zone in almost any location.



The distributed Tropos mesh architecture is capable of quickly and seamlessly routing around interference and congestion bottlenecks.

RF resource management

PWRP uses patented algorithms to continuously and dynamically optimize the use of the available spectrum:

– PowerCurve™: This distributed algorithm dynamically increases or decreases transmission power levels and continuously adapts the link data rates to maintain the reliability of each wireless link and also maximize the number of concurrent links. This stops, for example, "loud" routers from drowning out nearby "conversations."
– Airtime Congestion Control™ (ACC): ACC is designed to provide consistent performance for a large number of users, especially under heavily loaded network conditions, thus overcoming a well-known shortcoming of 802.11 MAC.
– Adaptive noise immunity (ANI): ANI adjusts chip-level packet detection parameters in real time to minimize false detection events and maximize receiver sensitivity.

Multilayer security

Security-wise, wireless networks are more vulnerable than traditional wired infrastructures, so Tropos' comprehensive security approach is based on:

– Open-standard security mechanisms that have undergone extensive scrutiny by the security community, such as IPSec, IEEE 802.1x, IEEE 802.11i, AES encryption, SSL/TLS, FIPS 140-2, etc.
– Robust security at every layer, from the physical hardware (eg, tamper-resistant, ruggedized hardware) right up to application-level traffic protocols (eg, HTTPS-based security).
– A security approach that allows granular, operator-specified policies to ensure the logical separation of the multiple applications running on the common infrastructure → 1.
– Software that adapts to the evolving threat landscape and that encompasses the latest security standards and requirements.

Outdoor optimized router

The Tropos router hardware has a battery backup and is ruggedized for operation in the most challenging operating environments. The radios are designed for optimal outdoor performance: They can transmit up to the maximum allowed transmission power level and they offer the industry's best receiver sensitivity.

Open standards

The Tropos solution set/technology aims to provide maximum interoperability and investment protection through support of all relevant open standards at every

3 Tropos router at EOG Resources exploration site

PWRP is a dynamic, wireless-aware routing protocol that allows mesh routers to perform end-to-end measurements of path quality and use these measurements to make routing decisions that result in the highest throughput.

layer of the protocol stack including IEEE 802.3 Ethernet, IEEE 802.11 Wi-Fi, IEEE 802.1x access control, TCP/IP, etc.

Advanced control and analysis

Tropos Control is a software application that provides comprehensive network management to streamline the deployment, optimization, maintenance and control of large-scale networks.

Mesh applications

There is a huge number of possible applications for ABB's mesh 802.11 solutions.

Smart grid applications

An advanced metering infrastructure (AMI) is just one of many applications that are required to fulfill the vision of the smart grid. However, demand management and response, distribution automation and control, outage management, and mobile workforce applications are also needed to make the vision a reality ➔ 1. Deploying and managing separate networks for each application is not cost-effective. A single, standards-based, high-performance network, such as Tropos, that aggregates communications for multiple applications is not only simpler to manage, but also yields an attractive return on investment ➔ 2.

In the coming years, additional applications for smart grids related to distribution automation, distributed generation, electric vehicles and video security will create a new appetite for high-bandwidth and low-latency communications that only a scalable broadband network like Tropos can provide.

Burbank Water and Power (BWP) in the United States is using Tropos for AMI, demand response and distribution automation. With a smart grid, BWP seeks to flatten demand peaks (to avoid having to build new generating plants) and accommodate the growth in electric vehicle numbers. The utility also plans to segment data traffic across different user groups and applications and share the network with other city departments.

Open-pit mining applications

Safe and efficient operation of open-pit mines requires precise coordination of some of the world's largest and most expensive machines in settings characterized by punishing heat or cold as well as extreme shock and vibration. Maximizing productivity in operations and maintenance can yield substantial improvements in profitability and safety.

The Tropos solution includes a suite of algorithms for efficient RF spectrum management and optimal spatial frequency reuse.

Wireless communications can significantly enhance the efficiency, productivity, safety and security of open-pit mines. A wireless network enables truck and heavy equipment telemetry data, operational and surveillance video feeds, safety and security system information, highwall scans and field data that drive mine management software all to be transmitted to a central location where the data is monitored, analyzed and acted on in real time.

The PotashCorp-Aurora phosphate mine in Aurora, North Carolina, has deployed a Tropos network with fixed and mobile nodes that provides equipment telemetry, real-time vehicle monitoring (speed, temperature, tire pressure, etc.), manufacturing process data and voice over IP (VoIP) communications.

Oil and gas applications

Measurement, logging and adjustment duties at remote rigs and wellheads are often performed by well tenders who travel long distances to site. However, wireless communication enables remote monitoring, in real time. This makes better use of skilled resources, speeds problem resolution and reduces travel time. In addition, a wireless network can provide cost-effective voice and high-speed data services to field facilities even in areas that lack cellular coverage.

EOG Resources, an oil and gas company operating in North America, owns very remote sites where cellular coverage is absent. The Tropos networks they have implemented provide their workforce with connectivity between these sites and the operational control center. This leads to improved operational performance as well as increased workforce security → 3.

Container port applications

Busy container ports, with large, constantly moving metal objects, present a particularly challenging wireless network environment. In one of the largest Mexican ports, for example, Tropos is successfully being used for tracking and real-time location of shipping containers both outdoors and in warehouses.

Smart city applications

In smart cities, multiple city agencies can benefit from a Tropos wireless communications network. For example, Oklahoma City's network of Tropos fixed and mobile wireless routers, covering 1,600 km^2, is used by more than 180 city applications, including:

- Mobile broadband in police vehicles, allowing 1,500 officers to spend 100,000 more hours per year in the field.
- Several hundred IP video cameras for monitoring and surveillance.
- The building inspection agency, allowing inspectors to be more productive in the field and reduce application turnaround time.
- Traffic signal controllers in the downtown area.

Simple and safe

ABB's patented algorithms and software in the Tropos product line, along with its industrial-grade hardware, put the company ahead of competitive alternatives in terms of reliability, performance and ease of maintenance, while providing easy access for thousands of different Wi-Fi standards-compatible endpoint devices.

Many applications require a wireless broadband solution with high resilience, security and scalability. ABB provides these features, allowing customers to build and operate high-performance communications networks enabling their applications to operate in multiple industries.

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Reference

[1] P. Bill, M. Kranich, N. Chari, "Fine mesh: Mesh 802.11 wireless network connectivity," *ABB Review 1/2013,* pp. 42–44.

The right fit

ABB partners with a family-owned company to power floating flow pumps

OSCAR AVELLA – Partnership can be defined as a collaborative agreement between two or more parties in which all participants agree to work together to achieve a common purpose or undertake a specific task and to share risks, resources and competencies. ABB has a strong history of successfully forming partnerships with companies, big and small. A recent example is the story of how a small, family-owned Colombian engineering company is transforming traditional irrigation systems in the Middle East, and the key is a floating flow pump powered by ABB process performance motors.

1 Floating pump powered by ABB motors

Founded by Eric Thiriez in Cartagena, Colombia, ETEC's initial goal was to build stationary flow pumps for government companies. Because, in some locations, the shore would be too soft for the weight of the stationary pumps, ETEC had to find an alternative to heavy construction. A pump floating in water was the solution.

The floating pumps are complete, integrated units, designed for continuous operation and capable of handling more than 5,000 l of water per second → 1. They can be installed and placed in operation in a short period of time, without the need for the civil construction work typically required for other types of pumps with similar or lower flow rates. The floating solution is applicable to a wide range of high capacity pumps, from axial flow to mixed flow and multistage pumps, and are used to move water in aqueducts, agricultural and aquacultural farms, flood control and irrigation systems.

Running the pumps

To power their floating pumps ETEC chose ABB's process performance motors. Last year, ETEC placed an order with ABB for 38 process performance squirrel cage induction motors → 2 to run the floating pumps destined for irrigation projects in the Middle East. "We decided to partner with ABB Motors and Generators, because they have a worldwide technical reputation that would guarantee the product that we were about to offer," says Thiriez.

The floating pump design requires a motor with a small frame that is also totally self-cooled with an enclosed fan and has high efficiency and low temperature rise. Thanks to its comprehensive portfolio, ABB was able to meet these requirements exactly: high energy efficiency (IE2 and IE3)[1], combination rated power Vs frame, and thermal margins that allow motor operation in outside environments up to 55°C at an altitude of 0 m above sea level.

ABB process performance squirrel cage induction motors run the floating pumps.

By partnering with ABB, ETEC was able to ensure a cost-effective solution with the floating pumps by using ABB high-efficiency process performance motors. ETEC offers the pump design with ABB's electric motors when a power source is available either by running cables into an electric network or through a local generator. For the floating pumps an electric motor has distinct advantages over a combustion motor – there are fewer failure points, less preventive maintenance and lower operating costs.

For ABB the partnership means long-term customer relations, an increase in the process performance motor business, and an important order intake. After the initial order, ABB received an additional order of 55 motors for the Middle East irrigation project. ABB continues to work with ETEC to develop a general performance portfolio for serial pumps, also increasing participation with process performance motors together with ABB softstarters to offer a complete pump solution.

2 Breakdown of ordered ABB process performance squirrel cage induction motors

Quantity	Output	Description
8	371 kW	– M3BP – Frame size 355
15	336 kW	– 380 V, 50 Hz – 1,500 rpm – IP55
15	485 kW	– IM2001

Oscar Avella
ABB Discrete Automation and Motion
Bogota, Colombia
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Title picture
ABB process performance motors are designed for demanding applications and energy savings.

Footnote
1 IE2 refers to high-efficiency motors according to IEC 60034-30 (2008); IE3 refers to premium-efficiency motors according to IEC 60034-30 (2008).

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Innovation

The opening issue of *ABB Review* for 2014 will be dedicated to innovations. Contributions being prepared include a look at some of the challenges around giant wind turbines, how to economize fuel with the latest breakthroughs in turbocharging and how advanced physics is being used to measure current with previously unknown levels of accuracy. The issue will also explore how tomorrow's drinking water can reach consumers more efficiently, offer a taste of what is new in simulation, and much more.

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