



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.

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” place-

ment). The former topology is appropriate, in most cases, for large data centers and the latter is usually found in smaller data centers.

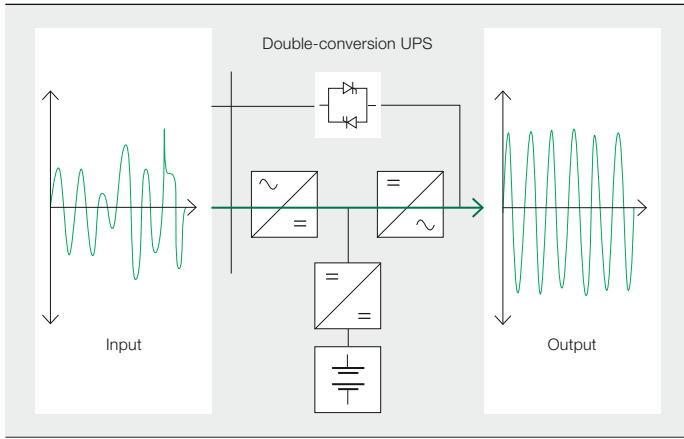
Servers are not the only elements of a data center that require UPS protection: Auxiliary devices and systems that manage cooling and safety, often called “mechanical loads,” are also critical for the smooth operation of the data center and ABB provides reliable backup power solutions for these, too.

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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:

$$\text{MTBF} / (\text{MTBF} + \text{MTTR}) \times 100\%$$

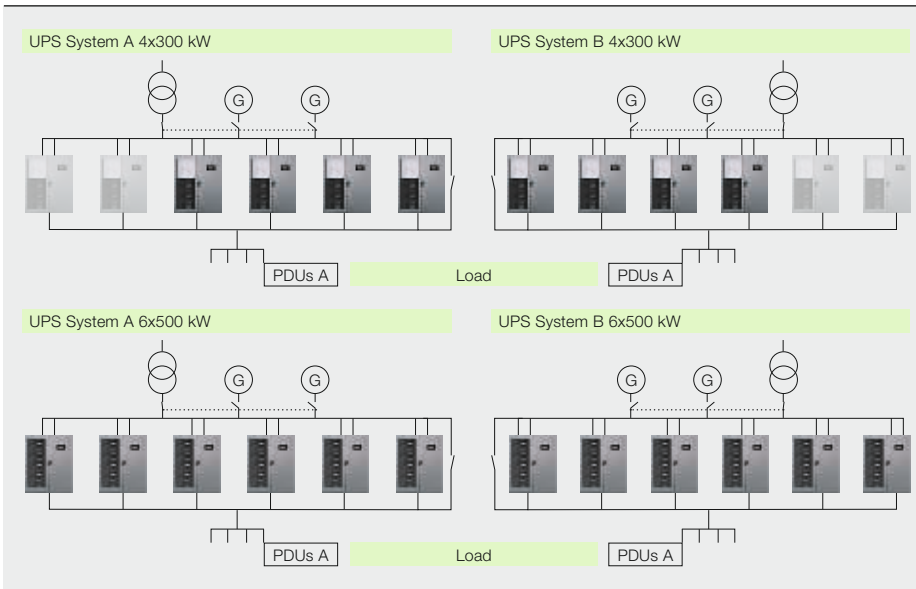
where MTBF is mean time between failures and MTTR is mean time to repair (in hours). These are common parameters in the UPS industry and both impact system availability. Modular UPS designs minimize the system’s MTTR.

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



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

Vertical scalability: one to five modules in one single cabinet



Horizontal scalability: cabinets in parallel configuration up to 3MW

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



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 unaf-

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.

ected 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.

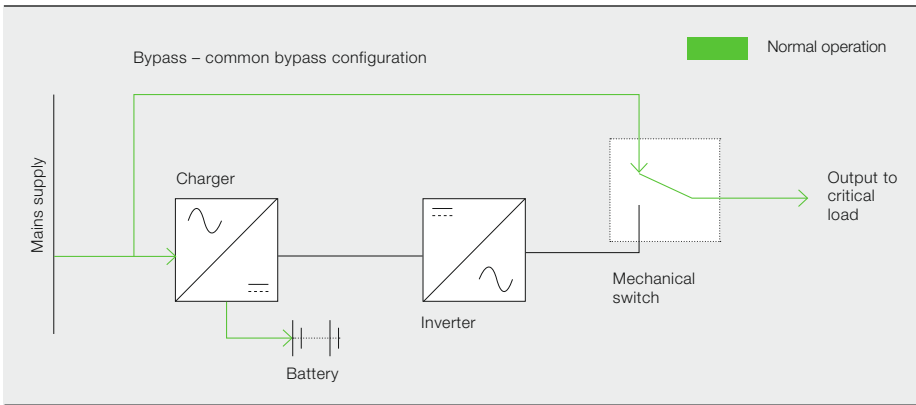
Hydrogen fuel cells exploit the fact that when hydrogen and oxygen chemically combine to produce water, electrical energy is also produced. They are significantly more expensive than batteries. Also, hydrogen is an explosive gas, so great care has to be taken with its storage. However, though in its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

Low total cost of ownership

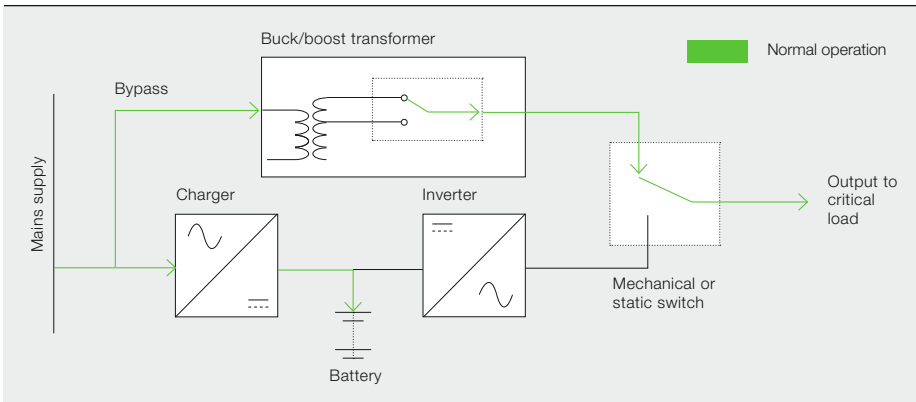
ABB UPSs have a very low cost of ownership, partly because of the modularity and scalability described above, but also because of their best-in-class energy efficiency. ABB's Conceptpower DPA 500, for example, operates with an efficiency of up to 96 percent. Its efficiency curve is very flat so there 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.

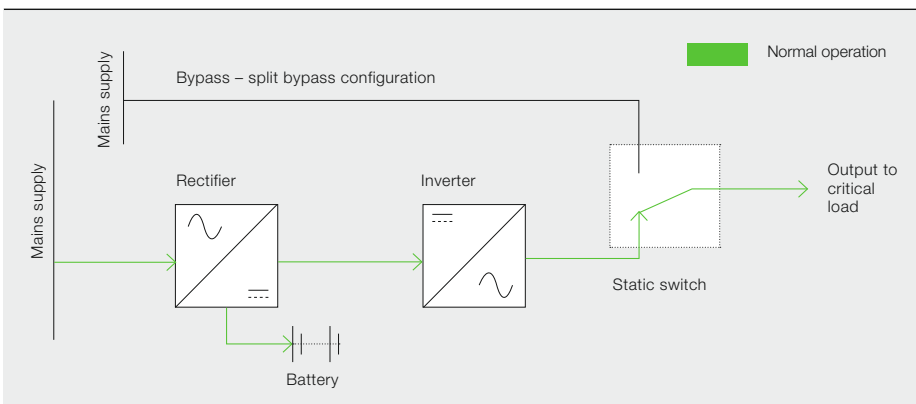
6 Standby UPS



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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