



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 CO₂ 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 sys-

tem 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 Alliance¹ 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, back-feed to utility).

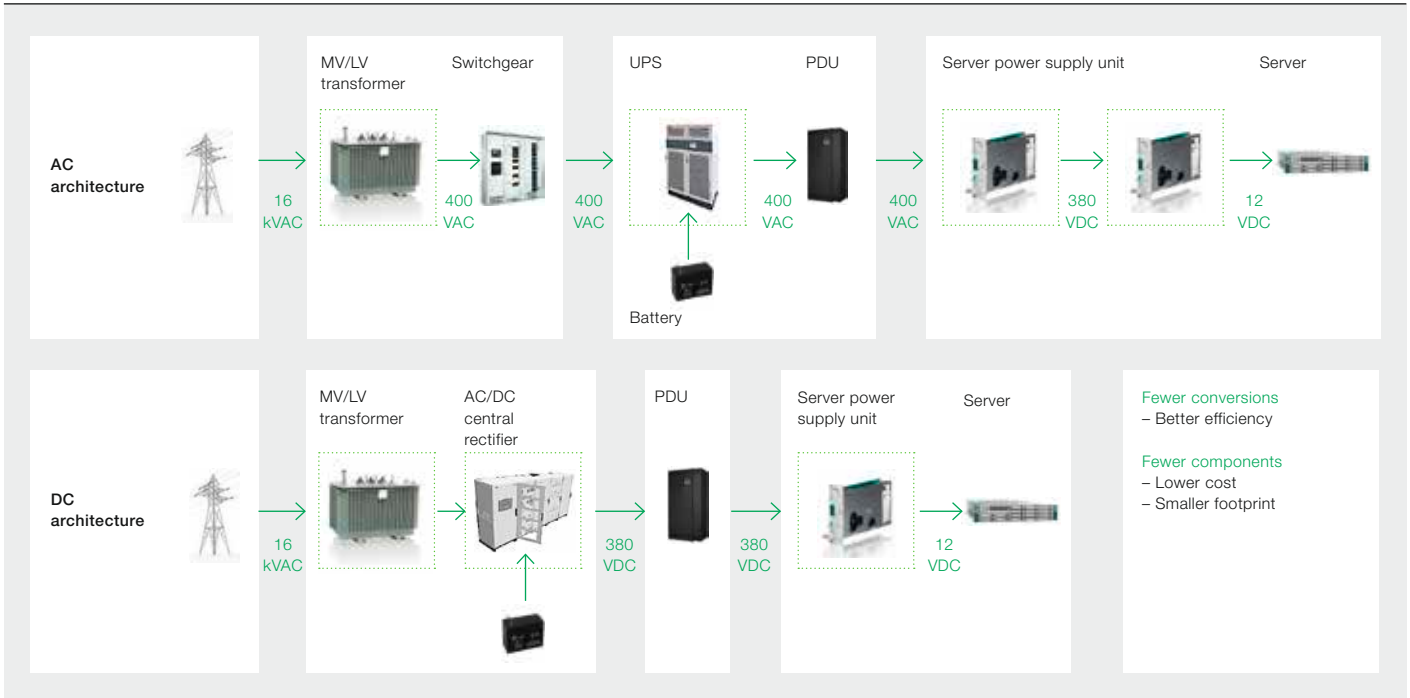
Rectification

The output of the medium-voltage switchgear connects directly to the central rectifier unit. Within this unit, there is first a medium-voltage switch disconnecter, 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.



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

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 iS power distribution units

Two redundant MNS iS 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 iRPP may additionally be used for this task, allowing more precise distribution. The MNS iS 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).

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

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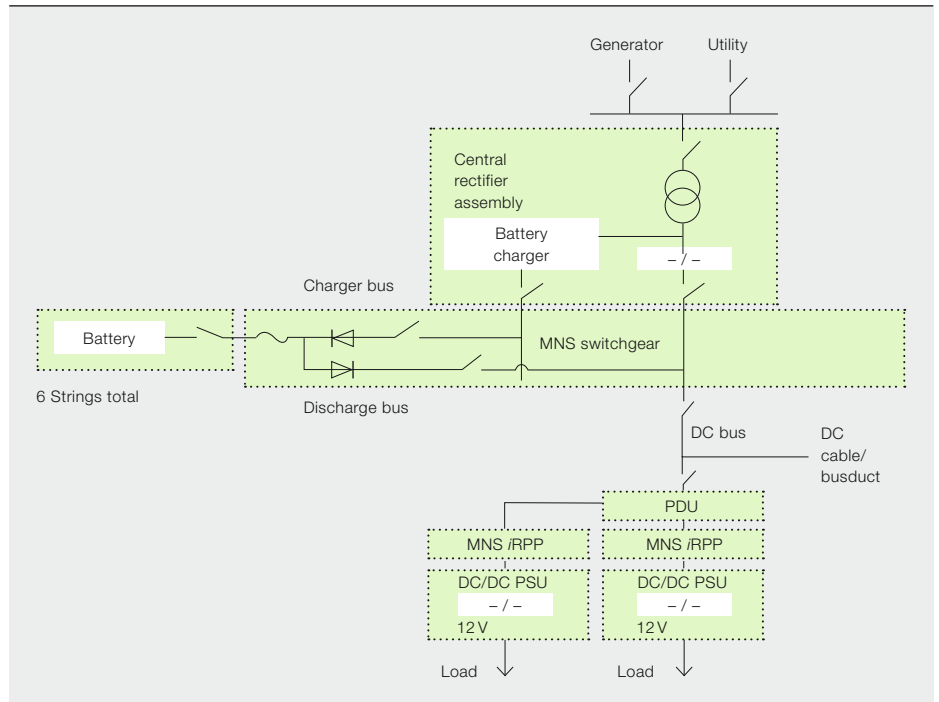
the energy to the MNS iS PDU (power distribution units), which are directly adjacent to the IT rooms and constitute a type of sub-distribution unit.

The MNS switchgear is designed for an operating voltage of 400V 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

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.

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

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).

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

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. 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

System comparison

Comparison of the circuit topology implemented in this project against conventional AC (as also used at green-Datacenter), shows that with DC, there are two less conversion steps in total → 2. First, there is no traditional uninterruptible 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

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.

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.

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 Data-center 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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