

INTELLIGENCE UPDATE

Emerging tech: superconductivity in the facility



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27 Oct 2025

EMERGING TECHNOLOGY SERIES

In this report, part of a series on emerging and potentially disruptive technologies that may be deployed in digital infrastructure, Uptime Intelligence assesses the use of superconductivity to distribute power inside a facility.

EMERGING TECHNOLOGY: SUPERCONDUCTIVE BUSBARS	
Key innovation:	Superconducting cables and busbars, carrying high currents at low voltage, enable operators to meet the power needs of high-density racks.
Potential impact (1 is low, 5 is very high)	5 Superconducting power distribution could enable otherwise difficult high-density deployments.
State of maturity	Research stage. No known public implementations.
Main drivers to deployment	Delivering increased power to dense racks requires heavy, bulky cabling (or a shift to medium voltage). Conventional busbars carrying high power can result in energy losses and pose safety concerns.
Main barriers to deployment	Unproven in a data center context. High capital expenditure. Lack of standards and staffing skills. Cryogenic systems introduce added complexity and resiliency concerns. Safety concerns relating to the use of high current and liquid nitrogen.
Possible date range for wide deployment	2035-2040
Key innovators/ companies involved	Startups adapting fusion energy infrastructure for data centers (e.g., Tokamak Energy). Specialist suppliers, including MetOx, Vision Electric, VEIR.
Key companies or type of companies most affected (positively or negatively)	Conventional busbar distribution companies; fusion companies. Operators/data center developers planning high-density (AI) data halls.

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Context

Data centers are becoming larger and denser, with some high-end AI hardware expected to demand hundreds of kilowatts per rack. Delivering this density of power presents a significant challenge for data center developers.

Data center designers are considering several options. Some are planning larger busbars, and many are considering the use of medium voltage power distribution (from 700 V to more than 1000 V) to reduce the weight and volume of conductors. However, this requires additional electrical equipment in an already-congested white space, and also affects safety, efficiency and cost (see *AI to trigger radical overhaul of data center electrification*).

Superconductors may provide a solution. They can carry 250 times more current per unit volume than conventional conductors; superconducting cables and busbars deliver higher power without requiring higher voltages or larger busbars.

Today's busbars carry up to around 500 amperes (A). Published designs suggest superconducting busbars could carry 20 times this current (10 kA) in similar physical dimensions. Superconducting busbars have been deployed in fusion test reactors, and there is now growing interest in repurposing the technology for data centers.

In addition to making high-density power distribution more practical, superconducting busbars could enable operators to distribute power throughout a facility in direct current (DC) form. DC distribution can cut costs by reducing some electrical conversion equipment. Although the concept was explored 10 to 20 years ago, it was eventually dismissed because it required large busbars, big switch equipment and high voltages.

Superconducting busbars could reopen the DC debate, making DC distribution practical at lower voltages, enabling both efficiency improvements and simpler power distribution.

It is worth noting that a move to DC would also increase the benefits of superconductivity. In AC installations, superconductor performance is limited due to losses caused by magnetic flux vortices. DC removes these limits.

Superconductors are also being proposed to enable last-mile connectivity to data centers in congested areas (see *Emerging tech: superconductivity for power delivery*).

The technology

Superconducting materials have no electrical resistance, delivering high currents in relatively thin cables and busbars. A superconducting cable or busbar can carry currents greater than 50 kA — a 1.2 kV connector can carry 60 MW of power.

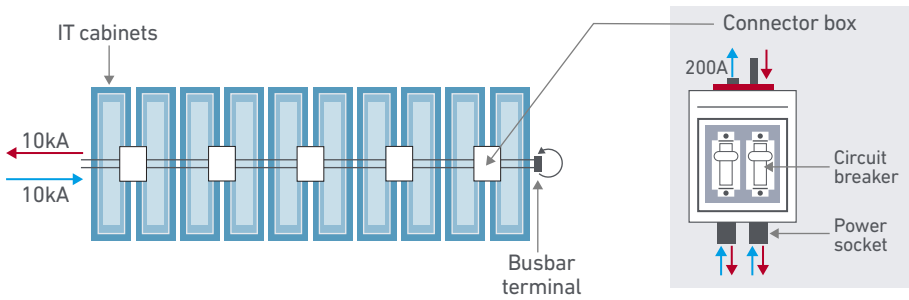
Commercial superconductivity products require the distribution of power at a very low temperature of -130°C (-202°F), which is achieved by immersing the conductor in liquid nitrogen. Confusingly, these products are referred to as high-temperature superconductors (HTS), because earlier superconductors required even lower temperatures.

HTS materials use compounds of rare earth metals, usually yttrium. Specialist manufacturers deposit HTS materials onto metallic tapes. These tapes are strengthened with layers of additional material and enclosed in an outer sheath to form superconducting cables and busbars, which are kept at cryogenic temperatures by using liquid nitrogen to circulate within the sheath.

HTS materials were discovered in the 1980s, but their use developed slowly until about 2015 when nuclear fusion startups began using HTS wires to create electromagnets that were strong enough to contain fusion reactions. Nuclear fusion companies also developed superconductor cables and busbars to distribute high currents to banks of electromagnets.

HTS busbars are of particular interest as they could substitute for conventional busbars, which are common in data centers. In 2022, researchers Professor Xiao-Yuan Chen and Dr Boyang Shen, of Sichuan Normal University (China) and University of Cambridge (UK), respectively, published an academic paper describing a design using a branched network of HTS busbars to power a data center (see **Figure 1**).

Figure 1 Superconducting busbars designed for data centers



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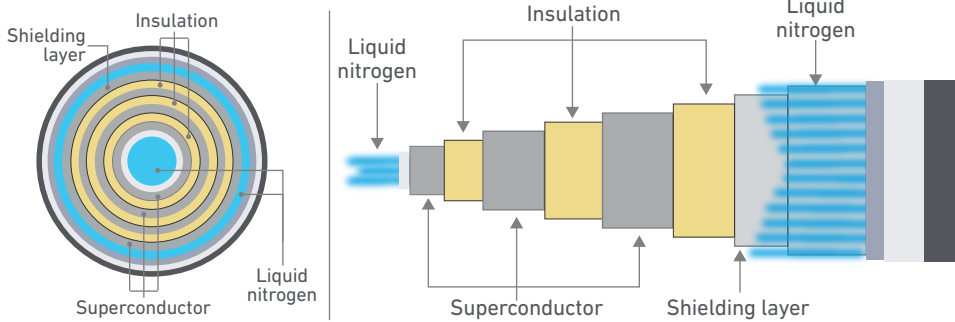
The busbars consist of an inner HTS core surrounded by a triple steel wall that contains an outer vacuum layer, as well as an inner space for liquid nitrogen circulation (see **Figure 2**). The branched system circulates DC current and provides a closed loop system for liquid nitrogen. A 100 kA busbar would be significantly smaller than a conventional copper busbar carrying the equivalent current: the HTS version has 4% (1/25) of the cross section of the conventional version.

In 2025, Vision Electric Super Conductors of Germany presented a commercial design to Uptime Intelligence. It uses 800 V DC HTS busbars, 200 mm in diameter, to connect the power from the facility's entry point at the UPS directly to the rows — or “pods” — of high-density racks, where the current is taken off the busbar and stepped down to 48 V for rack-level distribution.

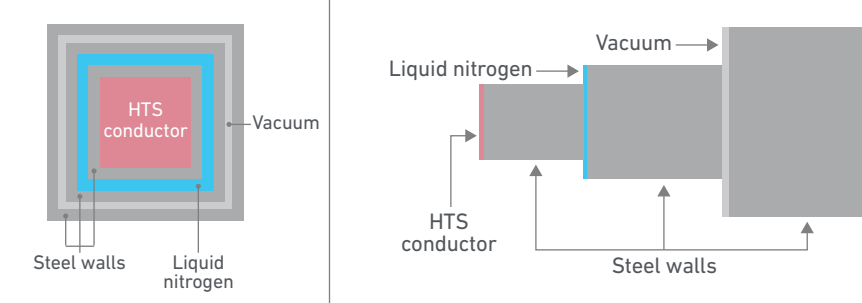
Vision Electric advocates DC distribution, both for improved superconductivity (as discussed above) and for operational reasons: DC distribution could improve integration of on-site DC power sources such as fuel cells and solar panels.

Figure 2 HTS cables and busbars

HTS cable



HTS busbar



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Implementations

To date, research into HTS for data centers is at an early stage, with little information available. UK-based Tokamak Energy has stated publicly about adapting its HTS busbars for data center use. Vision Electric has developed HTS bus bars for aluminium smelting plants and published papers proposing their use for DC distribution in data centers. In the US, VEIR has developed superconducting cables for grid use and has plans to offer HTS conductors to data center operators.

Hyperscaler operators are reputedly developing unpublicized trials of superconducting busbars, most likely in partnership with the specialist providers mentioned. At least one mainstream power distribution company is developing a position paper on the potential use of this technology.

The Open Compute Project (OCP) is understood to be incubating a group for superconductor data center specifications with several interested participants.

Economics

Superconductive busbars will have a higher capital expenditure than conventional alternatives. The most significant part of this cost will be the busbars themselves, which require exotic materials and expensive manufacturing techniques.

Cryogenic systems will also add to the capital cost, although such systems are already widely used in the food and pharmaceutical industries. These systems will increase operating expenditure, since liquid nitrogen is a commodity. However, Vision Electric reports that fulfilling a data center's cryogenic needs can be cost-effective, as it only requires occasional truck deliveries rather than operating an on-site nitrogen plant. Furthermore, well-insulated busbars require only about 2 W of cooling per meter and need occasional topping up rather than a continuous supply of liquid nitrogen.

In return, HTS busbars can offer substantial savings in power usage. Conventional busbars have resistive heating, which consumes electricity and increases cooling requirements. HTS busbars eliminate these losses. They also reduce the need for power-conversion equipment and expensive medium-voltage distribution equipment. Suppliers estimate that these savings can easily offset the cost of operating busbar cryogenics.

As rack densities increase, the escalating cost of conventional power-distribution equipment and falling HTS material costs will tip the total cost of ownership in favor of HTS.

In 2022, researchers Shen and Chen estimated that HTS busbars would cost about 15 times more than conventional ones, with a projected 17-year payback period based on 10 kW racks. By 2025, the landscape has changed. Engineers at companies such as Nvidia, Schneider Electric, Siemens and Vertiv are grappling with delivering redundant power to racks with densities above 500 kW, and the cost of HTS materials has fallen. Growing demand for HTS material has driven up production and significantly reduced costs. For example, a fusion test reactor can require thousands of kilometers of HTS wire. To meet this increased demand, HTS manufacturers have ramped up output, producing 10,000 kilometers of cable each year.

HTS busbars could now offer a payback time of around 5 years — or even less if their use eliminates a move to medium-voltage infrastructure or is combined with a move to DC distribution.

However, the cryogenic system introduces a potential point of failure to the data center. If the busbar temperature rises above the superconducting range, then the current must be shut off. Manufacturers report that HTS busbars can hold their temperature and remain fully operational for several days if the supply of liquid nitrogen is interrupted. While sudden leaks may cause a problem — and may require redundant busbars and cryogenic supplies — a resilient cryogenic system should be achievable. Meanwhile, lower-cost HTS conductors are being deployed in particle accelerators for high-energy physics research, in electricity power grids (see *Emerging tech: superconductivity for power delivery*), in more efficient wind turbines, in high-power applications (such as aluminium smelting), and in small, efficient high-voltage transformers.

Commercial activity

Any commercial ecosystem for HTS busbars is nascent.

Vision Electric and VEIR are publicly offering superconducting busbars for data center use, although Uptime Intelligence is not yet aware of any successful implementations. Fusion developer Tokamak Energy is expected to introduce HTS busbars for data centers but has not disclosed further details.

HTS specialists currently lack experience in the data center sector and are unlikely to gain traction without a partner. The most likely entry points into the data center sector will be through trials with hyperscalers or strategic partnerships with major data center infrastructure companies (as discussed earlier).

In 2025, US-based HTS wire manufacturer MetOx hosted a workshop on the use of HTS in data centers, which was attended by significant data center product vendors. However, there were no formal product or strategy announcements.

Drivers and barriers

Drivers for the adoption of HTS power distribution in the facility include:

- HTS busbars can power large numbers of dense racks without requiring medium voltage and/or large amounts of electrical equipment.
- HTS busbars do not generate resistive heat, reducing costs for electricity and cooling requirements.
- HTS busbars operating in DC mode will minimize the need for conversion equipment and simplify the connection of on-site DC power sources, such as fuel cells or solar panels.

Barriers to the adoption of HTS distribution include:

- HTS busbars designed for fusion reactors need to be redesigned to fit data center requirements.
- Early HTS busbars will be expensive.
- Designers need to create cryogenic systems that match data center resiliency requirements because the HTS infrastructure requires continuous cooling.
- Suppliers need to demonstrate that HTS busbars do not pose unacceptable arc flash risks or cryogenic hazards, such as frostbite. The risk of asphyxiation from a sudden nitrogen leak is considered to be highly unlikely.
- Although the technology has been proven in grid applications, data center products, and implementation experience are lacking.
- New HTS busbars will be proprietary until relevant standards are developed.

The Uptime Intelligence View

HTS conductors could become a critical technology in high-density data centers. They may also drive another significant change by enabling DC power distribution.

Uptime Intelligence expects that HTS power distribution within data centers will be an active area of research and development for years to come — some of it confidential. If early tests prove successful, public pilot projects could emerge in 2026. Wider deployment will require practical public standards, and work on these could be in progress by 2027.

Other related reports published by Uptime Institute include:

Emerging tech: superconductivity for power delivery

AI to trigger radical overhaul of data center electrification

Why DC racks are still rarely used outside of hyperscalers

ABOUT THE AUTHOR



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