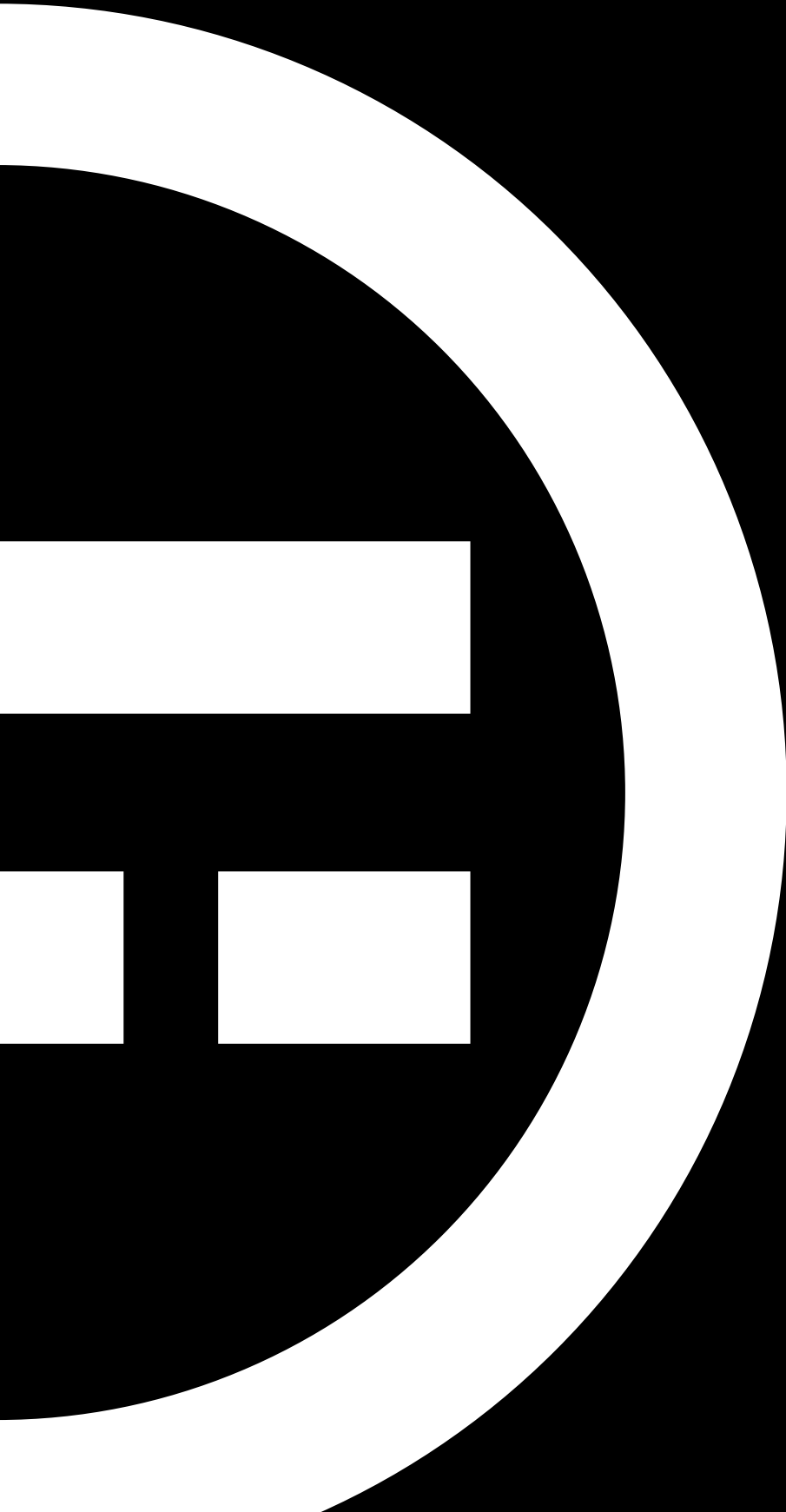




Direct current

The DC factory

Simply do it – DC is already being used in industry today

Connectors and switches

New products make old technology fit for the future

The DC setup

What is needed to make direct current safe – from partners and organizations

FACTS AND FIGURES

Power transmission

750 km

is a reasonable distance for high-voltage direct current (HVDC) transmission in outdoor systems

4,300 km

the longest HVDC transmission connection: Australia to Singapore

Industry

8–12%

gain in energy efficiency when switching from AC to DC in a factory

<50%

copper savings

<25%

fewer electronic components

Traffic

20%

range gain through recuperation

22 kW

max. capacity of AC charging stations

300 kW

capacity of DC charging stations

Data centers

416 TWh

of all electricity consumed in 2023, with the trend rising

3%

of worldwide electricity consumption

266%

increase in electricity consumed by servers since 2017

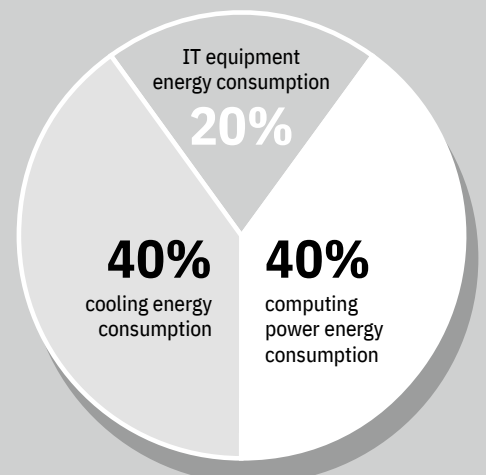
Power generation

2–10%

of direct current from the solar panel is lost via the inverter

10–20%

of energy is lost when solar power is stored in batteries





Dirk Görlitzer,
CEO Phoenix Contact

The future is here

Dear readers,

Direct current is one of the key phrases that, in the current climate of the energy transition and carbon reductions, is on everyone's lips. But what is really behind this new old technology? What are the advantages of direct current? Do projects that use direct current already exist? Who can help when information is needed? And are there any products that make the use of direct current as easy and safe as possible?

We aim to discuss some of the answers to these questions in this edition of the magazine, because it is a fact that industrial systems in which direct current is used successfully already exist. There are already experts who have the necessary expertise to handle this alternative to alternating current safely. And there are exciting new products that make direct current as safe as we are used to in the world of alternating current.

Phoenix Contact is one of the world's pioneers when it comes to direct current. We not only develop the most suitable components, but also set new standards in the application with our own DC factory. And we are helping to develop the urgently needed standards in international organizations together with our market competitors. We are doing this because we are convinced that direct current is an important building block for successfully mastering the energy transition and bringing our vision of an All Electric Society a good deal closer.

Legal notice

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The leap into reality

Lots of people are talking about it. But in Blomberg, Germany, a factory building has already been erected in which, due to its sophisticated DC grid, production can actually be energy-positive.

A walk from the roof down to the basement of the innovative All Electric Society Factory shows exactly how direct current works in practice.



2,760

solar panels covering an area of
5,562 m² supply energy from the roof

1,090

kWp of electricity is the maximum
generated by the photovoltaic
system, which is then fed into
the DC grid via 10 inverters

1,701

m³ is the capacity of the ice storage
unit, which can convert electrical
energy into thermal energy

It is a sunny afternoon in Blomberg, and we are shivering a little on the roof of a brand-new factory building. Like a sea of glass, a blue-black blanket of solar panels undulates on the 11,061 m² roof of the new factory building in Blomberg. As soon as sunlight hits the semiconductor material, electricity begins to flow. Thin metal strips on the solar cells transport it onward via finger-thick cables to the DC Combiner Boxes that collect the solar energy yield. Just another day in solar life.

But this building is different: whereas elsewhere, inverters ensure that it is even possible to use the direct current from the solar system at all, the electricity here is fed directly into a local DC grid. “Systems like this one are the future: a DC grid optimizes the entire energy chain, from generation, through distribution, to storage, and consumption”, explains Tobias Lüke from Phoenix Contact. The project manager and DC expert likes to start his tours of the building on the roof. This is because renewable energies are an important reason why DC technology is on the increase everywhere. “Not only generators are increasingly working on a direct current basis, but also energy storage systems and loads: LED lighting has replaced the light bulb. Most electrical devices and production units work with direct current – and the demand is growing”.

Service station included

Charging stations are now a common feature of modern industrial buildings in the All Electric Society Factory. And they are important loads in the growing DC cosmos. Tobias Lüke therefore leads his group down to the first floor, where 10 energy dispensers are lined up at the entrance to the building. They were created in cooperation with the specialists from VTS Echarge. “They are also important building blocks in our building concept”, says Lüke. “In the future, company cars will be able to use bidirectional DC charging stations (DC = direct current) to not only charge their vehicle batteries, but also feed energy back into the system when needed”.

It becomes clear simply by opening a charging station that Phoenix Contact is well positioned in the field of direct current. “With our surge protection and device protection, DC circuit breakers, and DC charging connectors, we can ensure the safe operation of DC charging stations. The energy flows are controlled optimally by our power modules in combination with our in-house charging controllers”.

Bidirectional charging turns the electric vehicle into a kind of hybrid in the energy system, which can take on two

Direct current is supplied to the All Electric Society Factory directly from the roof – generated by 2,760 solar panels





Direct refueling:
The energy is fed from
the DC grid to its loads
highly efficiently; in
this case for mobility

different roles: When charging, it is a load in the DC grid, while when feeding into the grid, it takes on the function of a battery storage device – and helps to stabilize this grid.

Compensating peak loads

But that alone is not enough. Tobias Lüke closes the charging station again and points to the inconspicuous white container next to the entrance area of the building. “A stable power supply based on renewable energies also includes sufficiently large and reliable storage systems to compensate for fluctuations”, explains the DC expert. “And we can use these storage systems to compensate for peak loads (peaks) instead of drawing from the public supply network and save considerable operating costs”. In highly dynamic processes, it is precisely these peak loads that make industrial electricity so expensive. It has been shown that these peak loads can be reduced by up to 80 percent in DC applications through peak shaving. This makes every financial controller in the company happy.

What is unusual about this storage system is not only that it is directly integrated into the DC grid. Phoenix Contact is cooperating with Voltfang, a startup that works with e-mobility traction batteries. Tobias Lüke opens the container and points inside. “Cold, moisture, fast charging, and deep discharges: second-life batteries or batteries from overproduction for e-mobility usually have a higher load capacity than batteries specially developed for stationary applications. This advantage of the high cycling stability is exploited here. With optimized operating strategies and intelligent energy management, the service life of these battery systems is maximized and their efficiency for stationary applications is ensured for the long term. In an air-conditioned container such as this one, these batteries do not have to endure extreme

“Direct current optimizes the entire energy chain, from generation, through distribution, to storage and consumption”.

Tobias Lüke,
Project Management



If too much energy is generated by the system, it is buffered in a battery storage system, which is also highly efficient due to its direct connection to the DC grid

→

temperature fluctuations or perform at extreme peak performance. We give them a long second life”.

Thinking, steering, and controlling

However, the story of generation, storage, and loads in the DC grid is by no means complete without the control center. Tobias Lüke leads us into the technical catacombs of the building. We go through the in-house machine building department, which has a new home in the All Electric Society Factory, and down the stairs into the basement. The central nervous system of the DC power supply is located here. At the end of a hallway with whitewashed walls, the DC expert closes a door. In the long windowless room, it still smells like a new building. Control cabinet after control cabinet line the walls. The eyes of our guide, who is in his late thirties, begin to light up as he walks down the long row. “This is where the heart of the system is, the low-voltage main distribution for our 650 V DC network”.

The control cabinets do not only integrate photovoltaic systems, battery storage systems, and charging stations into the system. If necessary, electricity from the public grid is drawn in here – and any surpluses fed back. “Our power modules are ideal for setting up industrial DC grids. They can also be operated bidirectionally, i.e., in both directions”, explains Lüke, opening a control cabinet in which the modules are aligned like drawers. “Thanks to the modular design, control cabinets can be assembled flexibly and the power can be scaled very easily as required”.

Less copper and more power savings

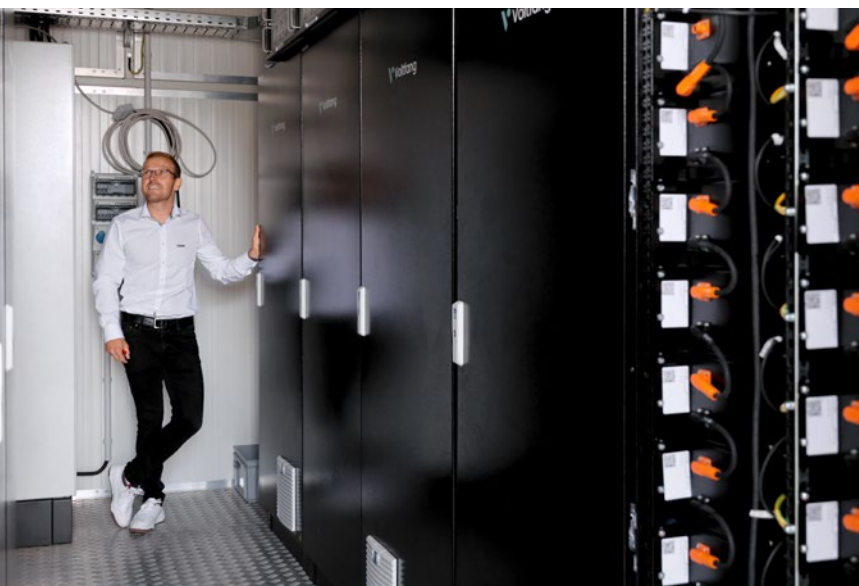
One turn, then the control cabinet is open. A whole mass of red and white in intimate togetherness, positive and negative in the DC grid. It is immediately clear to see that the cables and other components are significantly smaller than those in conventional distributions. This is another advantage of DC. “DC grids require less copper for power transmission. This saves up to 55 percent of this expensive raw material”, says Lüke. The red and white strings from the photovoltaic system also end up here in the control center. They supply to the DC bus via DC/DC converters with a total power of 120 kW.

The DC electricity is distributed to the production area by the low-voltage main distribution. Here, the lighting works directly with the power from the DC grid. Two branches are routed to a direct connection to the production machines. “In the DC grid, we can use the braking energy of robots and drives and return it directly to the system”, says Lüke, explaining the next important advantage of direct current. “This recuperation alone can achieve an increase in efficiency of up to 20 percent depending on the application.”

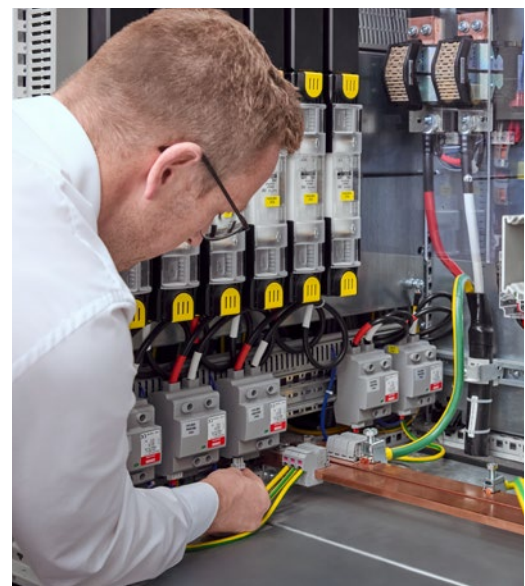
If, despite all the loads and storage systems, excess energy is still available in the DC grid, the bidirectional AC/DC converters feed this power back into the public AC power grid in compliance with grid conditions.

The concept becomes tangible

Wherever DC loads need to be safely switched in the All Electric Society Factory, we use our in-house miniature



Tobias Lüke is one of the drivers behind DC technology at Phoenix Contact



Connectivity and automation with the latest components

circuit breaker, the ELR HDC. It combines the five device functions of protection, switching, monitoring, pre-charging, and network capability. DC energy meters record the energy flows throughout the entire network. In order to connect DC loads together with plug-in connectivity, the ArcZero DC connector is used in the building. This enables arc-free plugging and unplugging under load.

The PLCnext Engineer software platform by Phoenix Contact handles load management and higher-level DC grid management and combines the individual areas into a comprehensive system. The controller also integrates data such as electricity costs on the electricity exchanges, weather forecasts, and up-to-date data from the measuring station on the roof into the building's energy management system.

Not just talk

The All Electric Society Factory in Blomberg already has a reputation throughout the industry, far beyond Germany's borders. Not just talk, but also action: direct current is already working here and now. This is demonstrated every day by the direct current production facility and its energy balance. However, "This system was designed exclusively for test purposes and operational tests", adds Tobias Lücke. Overall, the creators of this pilot project hope for further savings and increased efficiency. Among other things, the plan is to set up a small-scale wind turbine, an electrolyzer for hydrogen generation, and fuel cells, which in turn generate electricity from the stored hydrogen.

Phoenix Contact has been involved in researching and establishing DC technology for many years and is a founding member of the Open Direct Current Alliance



A sophisticated building control system works together with the energy management system

(ODCA). When the planning of the building began, there were hardly any components or standards for the use of DC technology on the market. Grid operators had little experience with DC systems. The search for suitable planners and installers proved very difficult (see page 10). Today, things are different, emphasizes Tobias Lücke. "With the available components, regulatory progress, increasing expertise, and collaboration with expert partners, it is also worth it for other companies to take the step to DC".

Dark has fallen in Blomberg. We have come to the end of the tour and Tobias Lücke closes the gate to what is currently one of the most innovative factory buildings ever. (is/lo) ■

ODCA – the empowering force

It is not always easy when you are at the cutting edge of technology. This is because much of what works in practice in your own environment cannot be mirrored in other applications. Systems must also be able to work together even beyond their own operational boundaries, otherwise ideas become expensive flops.

The direct current movement is developing rapidly. But for those companies wanting to save on operating costs via local DC grids, this is easier than ever now. The Open Direct Current Alliance (ODCA) has published the "System description for DC microgrids in the low voltage range" as the German pre-standard VDE SPEC 90037. VDE SPECs serve

as valuable reference documents for planners, installers, and end users. In particular in fields where standards are not yet available, they make the approval process much easier. Over 100 experts from more than 70 companies have developed and validated a comprehensive description of DC microgrids based on 10 model applications. The working group of the German center of excellence for electrotechnical standardization, the DKE (the German Commission for Electrotechnical, Electronic, and Information Technologies), has checked the recommendations and approved them for publication.

DC IN PRACTICE

• • •



DC made tangible

No matter how many advantages direct current has on its side, there are still massive reservations about using DC, even in expert circles. And there are far too few specialists who can not only plan but also install. Bernd Zeilmann is one of these rare examples.



Bernd Zeilmann is the General Manager of the Richter R&W Steuerungstechnik control technology company

Bernd Zeilmann can almost make the journey to Blomberg in his sleep now. The master craftsman of the Bayreuth Electrical Guild is one of the creators of the direct current factory on Flachsmarktstrasse Street. Whether in trade, industry, or research – Bernd Zeilmann is at home everywhere and knows exactly what works and where there are difficulties when it comes to direct current.

What drives a trained electrician and master craftsman from a traditional craft business to venture into such an innovative field as DC technology? It is immediately apparent that Master Zeilmann is passionate about innovation. “My goal is to maintain and extend the high quality of our work in the guild trade. This is the driver behind my interest in innovations and research and through this, I also became aware of the concept of the All Electric Society, which is a real opportunity to bring the energy transition that is needed to life.

At Richter R&W, we have always built switching devices and developed automation solutions for the machine building sector, which is strongly represented in our region, and have also dealt with software and controllers. With innovative power distribution based on direct current, we are extending our customer base and thereby supporting municipal and commercial customers on their

way to climate neutrality”. With this motivation, Zeilmann and his colleagues in the Bayreuth guild teamed up with the Fraunhofer Institute IISB in Erlangen with the aim of jointly developing solutions for the energy transition. The practitioners wanted to and continue to want to make the technology development faster, from the prototype, to the demonstrator, through to series production. “We are not competing nationally, but globally”, says Bernd Zeilmann, explaining the reasoning behind this.

How complex this enterprise can be is quickly demonstrated. A good eight years ago, the Fraunhofer Institute in Erlangen wanted to set up the first research DC grid. But at the beginning, even this renowned institute could not find a specialist company that was able to set up such a DC grid. The Richter R&W control technology company took part in the tender and was promptly awarded the contract for the DC power distribution. The savvy Mr. Zeilmann immediately thought to the future and also installed an innovative DC grid in his own facility.

Link to industry

In addition to planning and installing the DC grid in the All Electric Society Factory, the experts from Franconian Switzerland were most recently also commissioned for the →

“NExT Factory” of the DC pioneering company Schaltbau based in Munich. And the number of innovative projects is increasing. “We are currently in the process of testing bidirectional charging for the German Federal Ministry of Transport and Digital Infrastructure with a mobile DC grid that is housed in a container”.

Phoenix Contact and Schaltbau are now partner companies when it comes to direct current. And Bernd Zeilmann is the practitioner and creator, the link between the companies. “Today, we are able to offer DC grids, most of which use components from Phoenix Contact and Schaltbau”.

But the road to an in-house DC grid is still a rocky one. Bernd Zeilmann explains why. “A major sticking point is the regulations and standards in accordance with which such power grids are to be built. It is, of course, valuable for us that I myself work in standardization committees in the relevant standardization institutes. This allows us to contribute our experience from the projects directly and to promote innovative subjects such as bidirectional charging and DC grids”.

The innovative Zeilmann, who represents the Central Association of German Electrical and Information Technology Trades (ZVEH), eagerly advises scientists and political decision-makers, grid operators, and industry

to discuss how the energy transition can be realized. “It is a complex subject”, explains the Franconian. “The electricity sector is being coupled with the transport and heating sectors, and these interfaces did not exist on this scale before. This is uncharted territory”.

Bernd Zeilmann realizes the vision of sector coupling based on his wealth of experience. “I have been driving electric cars for many years. My grid operator can tell me which charging station can be connected to where. But they do not care at all about the car that is being charged. If I now want to connect a stationary battery storage system to the grid, I have to register it and have it approved. But what if the car can function as a mobile battery storage system with bidirectional charging?”

Independent island

We have solved this problem by using the certified power control unit from Phoenix Contact, which ensures access to the medium-voltage AC grid. Since the beginning of 2024, operators of controllable facilities have been free to decide whether to operate their DC grid independently downstream of the terminal point to the public grid or to allow the grid operator the option of intervening via direct control. After all, it cannot be the case that a grid operator reduces the power consumption of customer systems even though the customer needs their own electricity. These are new solutions that are currently in great demand”.

Richter R&W Steuerungstechnik

Founded in 1990 in Ahorntal, Germany, 50 employees, classic installation company. Customers: water treatment plants, wastewater treatment plants, swimming pools, environmental technology, and industrial machine building.

Schaltbau

Founded in Munich in 1929, 2,916 employees, core business railroad transportation, pioneer in DC technology, develops contactors and electromechanical switches and connections, the Eddicy brand is involved in the DC sector. Schaltbau built the ‘NExT Factory’ plant in Velden, Bavaria, and won the German Innovation Award in 2024.



The experts at Richter R&W plan, install, and program



Everyday life in the installation of systems: The quality of the grounding system is measured



Richter R&W is also a practical pioneer in the field of bidirectional charging

“We should be happy that the boom in e-mobility and heat pump has so far failed to materialize”.

Bernd Zeilmann,
General Manager R&W Steuerungstechnik

From Zeilmann's point of view, this personal responsibility makes sense. “Industrial systems require a lot of electricity. And connections to the medium-voltage grid are extremely expensive. One consideration is to switch to the low-voltage grid and cushion potential peak loads in production through battery storage systems and self-generation with a DC grid. Schaltbau's 'NExT Factory' assumes a 70 percent lower connected load. Schaltbau has a high-bay warehouse that is powered by a DC grid. Recuperation and battery storage systems are responsible for a large reduction in the connected load”.

The establishment of industrial DC grids has an important economic policy aspect. “The average price for industrial electricity is currently around 20 to 30 cents per kilowatt-hour. Electricity that is produced in-house only costs a one-off investment in technology and ongoing maintenance. As a result, the expected costs are around 6 to 8 cents per kilowatt-hour. And then everyone is also talking about subsidies for industrial electricity for German industry? The solution lies in a combination of self-generating and purchase with a dynamic electricity price!”

Skilled-worker bottleneck

The opportunities seem huge. But are there obstacles on the path to the perfect energy transition as well? Zeilmann sighs. “Of course, the shortage of skilled workers. What use is the best-ever component to industry if nobody can install it? When it comes to the subjects of heat pumps and e-vehicles, we should actually be happy that the expected boom has so far failed to materialize. We would not even have enough experts to be working everywhere. The electrical installation companies in the guilds are all fully utilized, at 100 percent. It is not for nothing that Asian corporations, for example, are now starting to buy up German manual trade businesses”.

Therefore, master craftsman Bernd Zeilmann is sending a clear message to the industry: “Due to the shortage of skilled workers, we have to automate prefabrication. The times when we were able to manually wire distributions on site are over. We can no longer manage this with our current workforce if we want to maintain the high quality.” (lo) ■

richter-rw.de

The safe visualizers

Lightning, sparking, melting metal – a short circuit in a DC grid can be an impressive experience. It is good if these forces do not occur uncontrolled. Even better if they are contained behind locked doors in the event of an occurrence.

We are meeting in the DC test laboratory in Blomberg. A legendary place, once simply called “Trabtech”, is now part of the Business Unit System Protection Technologies. Things are destroyed here. Naturally, the engineers talk about “testing up to the load limit”. But to be honest, anyone who exposes the test objects to the forces of electricity and voltage here would also like to see some sizzling.

But today, things will remain boring – this much can be revealed. This is because the Ri4Power system from Rittal, consisting of three control cabinets that are fed DC voltage under the expert supervision of Rainer Durth, actually have to cope with significantly higher loads in everyday life. However, the sheet metal containers do not have any glass panels in the front. So things will get a little bit jittery. “And pull”, says test engineer Durth, giving the command to the wanton short circuit. The copper ignition wires with standard-

specific cross-sections between the positive and negative poles begin to glow and start the desired fault arc. A bang, a glistening lightning bolt, then dark gray, dense smoke fills the main characters, the three control cabinets. However, their doors have remained closed.

→



White and red are the hallmarks of DC connections



Much more than just
“show cabinets”:
The Rittal Ri4Power system

“An electric arc is an
event that normally must
not even occur”.

Rainer Durth,
Master Specialist for Protection Technology Phoenix Contact





The DC specialist shows the screw connections that Rittal uses to make the side panels safe

“Our cabinets can withstand other loads”.

Zafer Cankurtaran,
Product Manager for Energy & Power Solutions, Rittal

10,000 

degrees is the temperature
that a plasma cloud can reach

In order to provoke short circuits, the team successively exposes the three control cabinets to ever-higher currents. At the peak, this is 8.6 kA.

Fifteen of these control cabinets of the Ri4Power system are already in the All Electric Society Factory. They must not be opened during operation. However, since the DC factory is not only supposed to produce, but is also a showcase for visitors and experts, the technology used should also be on display. So glass has to be integrated into the front. And this has to be as safe as possible. This is because “A fault arc is an event that should not normally occur”, explains Rainer Durth, Master Specialist for Protection Technology in the BU SPT and main member of the marathon testing program in the name of direct current. “If so, it means that an insulation fault has occurred and the current that is normally supposed to remain in the copper is now burning through the air as an electric arc.” With fatal consequences: the sudden heat ionizes the air, turning it into a plasma cloud which expands explosively. The pressure can cause control cabinets to burst. In the worst case, plasma, i.e., the glowing gas, will escape.

Inside the test cabinets, fuses, circuit breakers, and surge protection components from Phoenix Contact usually prevent an arc from occurring at all. If the electrical forces are unleashed, the cabinet itself must withstand an electric arc. A premiere for housings with glass door. “Our regular cabinets withstand very different loads than the 8.6 kA required here, as they are used on the low-voltage side of the All Electric Society Factory”, explains Rittal expert Zafer Cankurtaran during a visit to the company headquarters in Herborn. The engineer is the Product Manager for Energy and Power Solutions at Rittal. He is primarily concerned with the subject of DC technology.

The shell holds

For around a year, specialists from Phoenix Contact, together with experts from Rittal, the manufacturer of the housings, and from Richter R&W Steuerungstechnik, which equips the cabinets, prepared the fault arc tests. Test laboratories that can trigger a controlled fault arc and use it for testing purposes are

rare. The times required there are expensive and sought-after. Therefore, all steps must be carefully planned. “And fault arc testing in the DC grid with glass doors for our Ri4Power system was also uncharted territory for us. That is very special”, says Zafer Cankurtaran, explaining the situation in the Blomberg test laboratory.

Jörg Kreiling is Head of Product Management Energy & Power Solutions and one of the drivers behind DC technology at Rittal. He explains, “A short circuit in the AC range can be managed relatively well. Direct current with the same voltage is significantly more energetic and therefore more destructive if there is a fault arc. There are various safety levels in technical systems that must be observed”. Zafer Cankurtaran adds, “There are three protection classes for the fault arc tests. C means that the system remains highly available. The fault arc is extinguished during its formation, even before it can unfold its destructive effect. This is monitored with sensors in the cabinet. B means that the resulting fault arc remains in the field, i.e., it does not extend across the field. Protection class A is then the personal protection. This test is described by a standard. Around the system, indicators made of cotton or silk material are set up at a distance of 300 mm. Once the fault arc has been triggered, none of this thread or cloth must be damaged. The test cabinets in Blomberg passed precisely this test with flying colors”.

Far below the load limit

Have the tested DC voltage control cabinets in the All Electric Society Factory already reached the upper end of their performance? Jörg Kreiling smiles. “A short-circuit current rating of 10 kA was tested at Phoenix Contact. That is not much for us. We do not actually work or test our cabinets below 100 kA, i.e., in the range of low-voltage electrical installations. However, we can no longer use privacy doors in these applications, because they would simply disintegrate”.

The behavior of the housings at high pressures, which arise explosively when fault arcs occur, is important. The exploding gas wants to expand. Therefore, the first predetermined breaking points are rubber plugs in the upper housing

cover. These shoot out and ensure directional expansion, so that people in front of the cabinet are not endangered. If the uncontrolled energy is not regulated, the roof of the cabinet bulges upward so that the ever-increasing pressure can escape upward. If the pressure is increased further, the side panels begin to bulge outward. Normally, the walls are screwed at six defined points. In low-voltage distributions, there are up to 12 screw connections to keep the walls on the frame.

“The weak point is the doors, because they are movable. In the case of the pane, we use a toughened safety glass, which in the worst case



Zafer Cankurtaran is an expert in DC technology at Rittal

does not splinter, but rather crumbles. Double panes are simply far too heavy for the doors. I can reinforce on the hinge side, even by adding additional hinges. But on the other side there is a locking mechanism, which still needs to remain operable. And that is a critical point that has to hold”.

And these doors should open, because ultimately the practitioners have to get to the systems. Display cabinets are in demand, not show cabinets. (lo) ■

Visiting Rittal:
update.phoenixcontact.com/en/



Dat-Tri Trinh and Marc Klimpel know exactly what they can expect from “their” ArcZero

Electric arc tamers

Pull the connector out! In the world of AC voltage, this is often advised when electrical loads develop a life of their own that is too unregulated. In DC grids, this is a very bad idea that can end in fatal accidents. Until now...

Disconnection under load – that should not happen”. This statement from DC research circles is something that Marc Klimpel, a Development Engineer at Phoenix Contact, has in mind when it comes to the origins of the innovative “ArcZero” DC connector. “People held to this view for decades”, he says. “Disconnect operations were only possible once the electricity was switched off”. This is because an electric arc will occur if DC connections are disconnected without protection. This also happens with alternating current, but since the flow direction of the current is permanently reversed here, the AC electric arc is usually significantly shorter and therefore safer. Quite different from direct current, because the one-way flow of electrons does not want to let go of its flow direction here and also bridges longer distances via electric arcs during disconnection attempts. And it can burn at temperatures of several thousand degrees.

Disconnecting without switch-off

Therefore, until recently, disconnection operations were only possible after the entire system had been shut down. In terms of safety and operating convenience, DC grids were therefore hopelessly inferior to the AC grids. This led to numerous research activities, because firstly, the electricity generated from renewable sources is DC. And most loads also want to be operated with it. However, the general grid structure consists of AC grids that are safer and much more suitable for transporting power over longer distances. Therefore, the electricity is transformed on its journey from generation to consumption in batteries, displays, and printed circuit boards. In this process, a portion of the energy is lost.

Since 2018, Phoenix Contact has been working on making the DC current more user-friendly and manageable. This long development journey is bearing



Electronics in the connector make it possible to disconnect under load

innovative fruit: the “ArcZero” DC connector was introduced at the end of 2023. As its name suggests, it keeps the electric arc in check or, more precisely, “set to zero”. The trick: a small PCB inside the ArcZero monitors the status of the current connection. If you pull the plug, the PCB suddenly comes to life, draws its energy from the first sparks of the resulting electric arc, and extinguishes it within milliseconds.

Finicky testing

Developer Marc Klimpel describes the challenges during development. “For us in the BU, it was new to have electronics in our connectors. “In addition, active electronics that are designed for these voltages – this was also new territory for us”. The ArcZero connector is therefore being subjected to comprehensive monitoring. Klimpel’s colleague Dat-Tri Trinh is accompanying the ArcZero through its laboratory cycles from the pre-series development. He has therefore been accompanying the prototype from the development status to series production. He explains, “Each connector is electrically tested manually. No reject part leaves Production. They are rigorously inspected there”. This guarantees 100% safety and functionality”.

The right product at the right time, because direct current is a real boom subject. And the ArcZero is a milestone in the development of DC technology. Among other things, the innovative plug was voted electronics product of the year 2024 by Elektronik.net, the web service of the WEKA specialist media house. (lo) ■

Fast switching

Protect, monitor, and above all switch safely: The Contactron ELR HDC (Electronic Load Relay – Hybrid Direct Current) is the first multifunctional DC circuit breaker specifically developed for industrial DC applications.

The all-round talent enables arc-free switching in DC grids due to its highly efficient semiconductors and electrical isolation. The ELR miniature circuit breaker uses built-in sensor technology to monitor current, voltage, and temperature. And thanks to the built-in IO-Link interface, this data can be transmitted to system networks. This also enables remote access via control centers. The ELR protects connected loads against overloads, right up to short circuits. And this is extremely fast, thanks to the series semiconductor switch in less than ten microseconds in the event of a fault.



A photograph of two men, Martin Wetter and Christian Helmig, standing in front of industrial equipment. They are both wearing blue suits and white shirts. Martin Wetter is on the left, bald, with his arms crossed. Christian Helmig is on the right, wearing glasses, with his arms crossed. The background shows industrial machinery with various components and cables.

THE DC EXPERTS

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Direct current with a passion

They are the flagships of DC technology at Phoenix Contact. Martin Wetter and Christian Helmig are firmly committed to the Phoenix Contact mission statement, the All Electric Society. They are also convinced that direct current can make a valuable contribution to the success of the sustainable energy transition.

We are constantly surrounded by direct voltage in everyday life. “Every electrical device that has a display uses direct current – from washing machines and smartphones to car electronics. Fundamentally, every electric drive uses direct current and every battery stores direct current. There are very few appliances, such as old toasters and clothes irons, that directly use alternating current”, explains Martin Wetter. Christian Helmig adds, “With the advent of renewable energy generators, especially solar, direct voltage has become a big issue again. Whether in solar panels or wind turbines, the captured energy is first converted into direct current. And in electric vehicles, batteries with direct current drive the wheels”.

Both engineers are graduates of the Dortmund Institute of High Voltage Engineering, where they also completed their doctorates and worked together. Wetter, hailing from Münster in Germany, was drawn to Blomberg in East Westphalia way back in 1997. For a long time, he managed the world-renowned Trabtech overvoltage laboratory on the Phoenix Contact campus and is now responsible for the core business of Power Reliability. Helmig, a native of Westphalia, followed on five years later and is now Head of the Field Device Connectors unit in the Device Connection Technology division.

Advantage direct current

There are tangible arguments that play into the hands of Thomas Alva Edison’s upcoming successors: efficiency, storability, and resources. It is immediately obvious that with every transformation of energy, part of it is lost as heat. When electricity is generated by wind or the sun, it is initially available as DC voltage. The conversion to alternating current “eats up” around 20 percent of the original energy. This can be saved if direct current is used immediately as it is.

The second advantage is recuperation, i.e., the use of excess kinetic energy. “This is particularly easy with direct current. This is not only important for e-mobility but also in many industrial areas, such as high-bay warehousing systems and industrial robots. Energy is recovered when the movement is reduced”, adds the Innovation Manager, Wetter. “Efficiency is therefore one of the central issues when it comes to increasing the use of direct current.”

The ability to store it directly is another advantage. Energy from batteries is direct current. Direct current systems can store and retrieve energy directly in batteries without conversion. The complexity of the systems is decreased, which in turn leads to increased efficiency.

The next advantage is the conservation of resources, which begins with saving material, because the copper

cables required have significantly smaller cross-sections. And the required connected load, i.e., the amount of electrical energy that the grid operator contractually provides, can be around two-thirds lower than with a conventional AC connection. “This immediately saves money, even before a machine runs”, explains Christian Helmig.

Advantage alternating current

The advantages of alternating current come into play in terms of long-distance power transmission. Dr. Wetter explains, “If I want to transmit a certain amount of power, I need current multiplied by voltage. If I want to transmit a lot of power, I have to increase the current or voltage

The three DC trump cards



Efficiency

Energy savings of around 20 percent can be achieved by using direct current



Storability

Direct current is the energy form of battery technologies. This makes electricity directly storable



Resources

In addition to efficiency, direct current saves materials due to lower copper thicknesses

or both. However, the transmission losses along such lines depend solely on the current. In fact, they increase quadratically, which means that twice the current equals four times the losses. This is why we transmit high powers over long distances using alternating current with high voltages. It minimizes the transmission losses. The conversion is simple and extremely reliable with the appropriate transformers”. Alternating current has therefore become standard in the classic technology of distribution grids with a few large power stations and a star-configuration distribution grid.



The alternating current also scores points when it comes to handling. Martin Wetter says, “Actually, there is nothing that would not work with direct current. What we have achieved in the alternating current sector, however, is an extremely high safety standard. In comparison, around 3,000 people die in road traffic accidents every year in Germany alone, but there are just 30 deaths from electric shocks, despite the enormous prevalence”.

Why is it that working with direct current is still the domain of specialists? Christian Helmig explains. “The real difference between DC and AC in everyday life is the lack of the voltage zero point. If a device in operation is disconnected from the mains in an AC voltage grid, an electric arc is generated. But you hardly notice it, as it only lasts a fraction of a second. You have to be much more vigilant with direct current. Disconnecting a live device powered by direct voltage from the mains triggers a dangerous electric arc, which poses a massive risk to both the user and the material. This is why one of our product development goals is to achieve a similar level of safety for direct current technology that end users are accustomed to with alternating current”.



Dr. Christian Helmig completed his doctorate at the Dortmund Institute of High Voltage Engineering. Today, he is Innovation Manager for the Business Area Device Connectors

Cooperation makes DC powerful

This is where Martin Wetter comes in. “Thanks to new power electronics, we now have options to harness the advantages of DC voltage again. And we have developed our first products that are specifically aimed at the

Dr. Martin Wetter also headed the high-voltage laboratory in Blomberg for a long time



direct use of direct current. But there is still a lack of standardization”. Dr. Helmig adds, “Our ArcZero, for example, is the first connector that we have developed just for DC. A circuit that recognizes the contact is integrated. If I pull the connector under load, an electric arc is also created here, but it is only minimal because the electricity triggers the circuit”.

Wetter explains, “This demonstrates why we cannot switch everything over to DC straight away. A simple plug and socket pair is much more complex in design to achieve the same result. In simple terms, the world of alternating current is established. We are therefore also founding members of the Open Direct Current Alliance (ODCA), in which more than 70 companies have already joined forces to develop standards for devices. The system concept is more important than individual competition between innovations”.

Best example of a DC factory

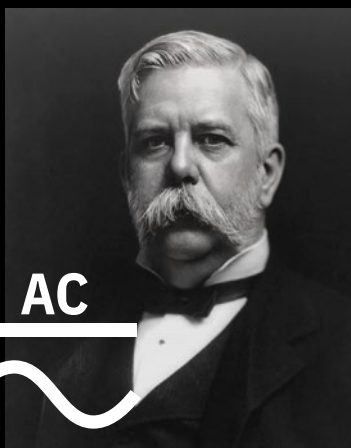
Dr. Helmig is confident. “As the number of showcases increases, it will become easier and easier to use this technology. In the meantime, customer interest is constantly increasing. Many of our industry customers want to know more about the experiences we are currently gaining at the All Electric Society Factory and also want to visit us”.

The two innovators are convinced of the success of their mission. “We believe that this technology makes sense. The advantages are clear. It fits perfectly with our vision of an All Electric Society, so the products to be developed are also a worthwhile investment in the future”. (lo) ■

Fighting tooth and nail

The dispute between the inventors Thomas Alva Edison (1847 – 1931) and George Westinghouse (1846 – 1914) is now regarded as the first format war in economic history. During this fierce battle, no trick was too dirty, especially for the legendary Edison.

In the early days of electricity, small, regional power grids were set up initially. Lighting by means of carbon arc or carbon filament lamps was the central task of the new form of energy, and the first small direct current motors were added. Edison developed the carbon filament lamp, which required



George Westinghouse established the alternating current system

direct voltage. The ideal voltage for operation was 110 volts. Edison began building the first power stations in the early 1880s.

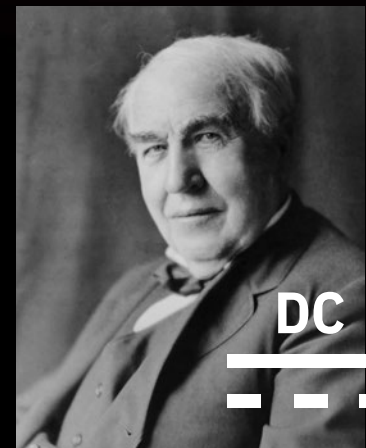
The transformer was invented in 1881, making it possible to transport large amounts of energy cost-effectively and over long distances. Nikola Tesla invented and introduced two-phase alternating current in 1887. This meant that there were two competing technical systems and a race to see which technology would establish itself on the market.

It quickly became clear that alternating voltage had decisive technical advantages. But Edison tried to push through his favored direct voltage by any means necessary. He predicted that users of alternating voltage would die quickly, tried to use patent tricks to promote his direct voltage networks, and went so far as to electrocute animals in public experiments. Naturally, fed from alternating voltage networks.

Nevertheless, the AC power grid prevailed. Westinghouse was commissioned to supply the 1893 World's Fair in Chicago in 1892. At the same time, he introduced an



incandescent lamp that circumvented Edison's patents. This decided the war. Edison later admitted that his insistence on DC grids was the biggest mistake of his career.



He is considered one of the most brilliant minds of his time: Thomas Alva Edison

By the middle of the 20th century, all of the DC grids in Europe had disappeared. In New York, on the other hand, 4,600 customers were still being supplied with DC voltage in 1998. However, direct voltage is now experiencing an unexpected renaissance. (lo) ■

“Wherever there are photovoltaics on the roof and charging stations in front of the building, wherever storage systems are used and machines are powered, direct current becomes an exciting alternative”.

Dr. Christian Helmig,
Head of Field Device Connectors Phoenix Contact

phoenixcontact.com

