Connecting AC with DC — The Future of Energy Transition

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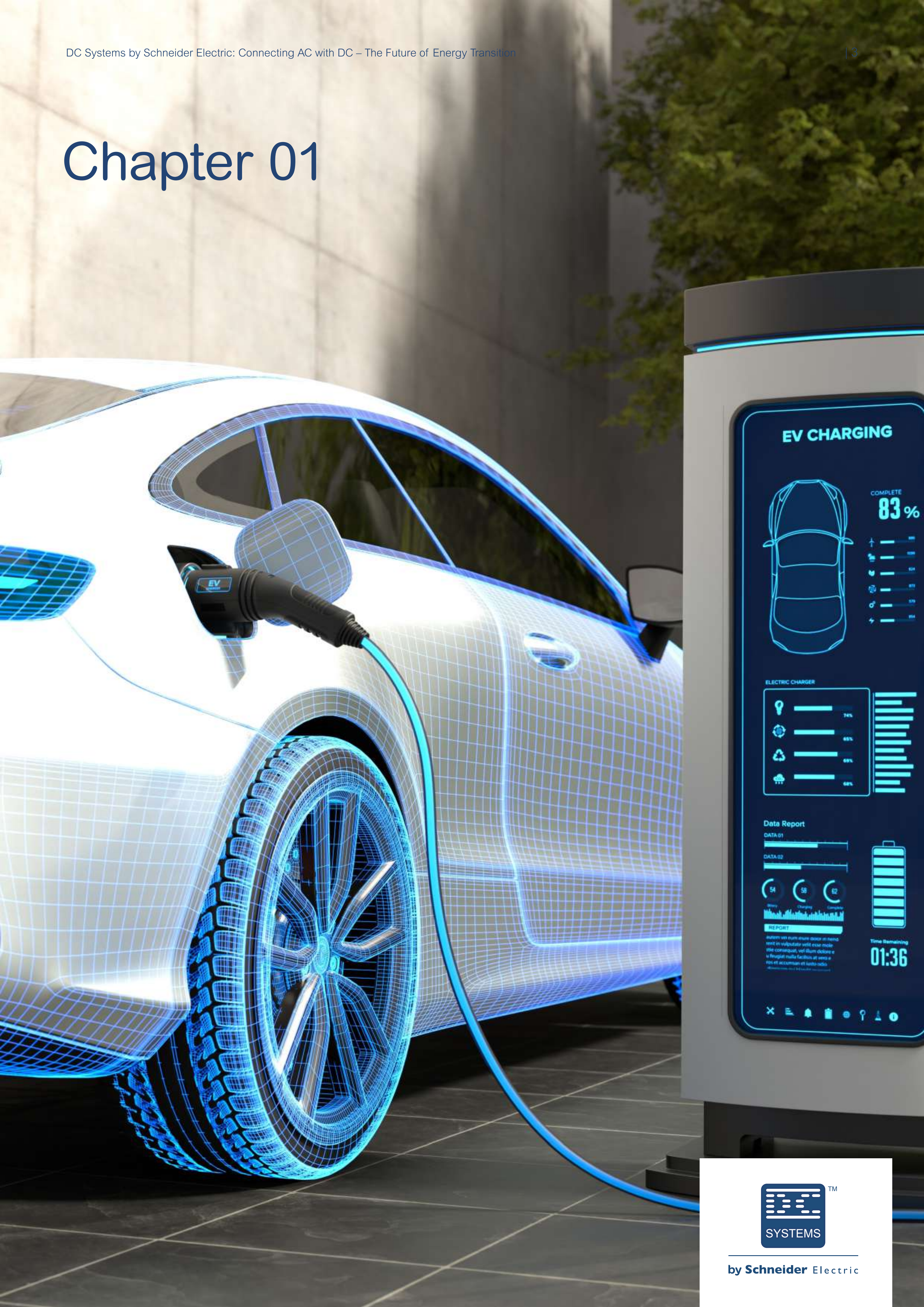
Chapter 01



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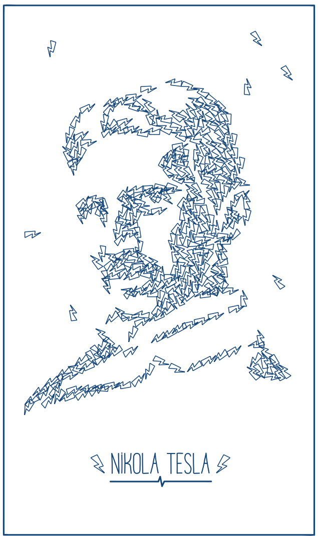
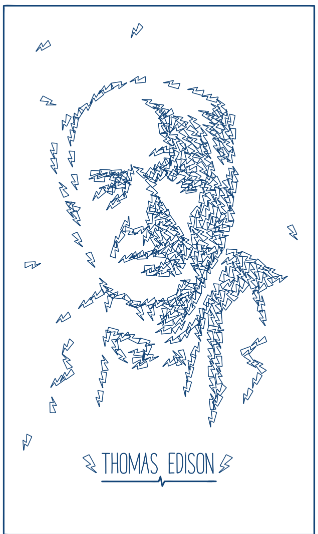
Demystifying DC in the new energy landscape

What is the market situation?





The way we generate and transmit power is changing. As renewables and prosumers (such as data centers that both produce and consume energy) increase, so does the complexity of energy infrastructure. Typically, we rely on large fossil-fueled power stations, where alternating current (AC) enables efficient long-distance power transmission. But now, **decentralized, renewable, and local power sources are growing in popularity** — along with the integration of local direct current (DC) distribution.

AC's longtime ubiquity has meant some people are cautious when it comes to DC and lack a full understanding of its usage, benefits and safety. Yet much of the digital world already runs on DC: our computers, mobile phones, electric vehicles and other day-to-day devices use converters to flip from AC to DC, unfortunately adding potential e-waste. It's the same story for renewable energy systems like solar panels and batteries. In fact, research by European Distribution System Operators (E.DSO) predicts that the proportion of energy consumed in DC at home will reach 80% by 2030.

The truth is that AC and DC can, and should, coexist happily in the new energy landscape, and the microgrids of the future will rely on a relationship between the two.

Over a century ago, AC, proposed by Nikola Tesla, won the 'War of the Currents' due to the ease of scaling up or down voltage value, thereby reducing transmission losses. Almost immediately the use of simplified generators and motors ushered in the Industry 2.0 era. DC has made a comeback in recent decades thanks to the increased demand for extra high voltage transmissions lines that complement the AC network.

Today, with new innovations such as the development of renewable energy generation and growth of new DC loads like electric vehicles, DC can play a vital role in the further commoditization of microgrids.

DC can accelerate energy transition, which is faltering behind carbon neutrality targets today, due to grid congestion on both supply and demand sides.

80%

of energy consumed in homes is predicted to be **DC by 2030**, according to research by European Distribution System Operators (E.DSO).

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Why has it not been addressed yet?

While AC distribution is top-down, AC prosumer installations are much more complex — especially when they can interact with the grid, during normal or abnormal conditions due to the need for synchronization or for grid code compliance. The largest problem is integrating centralized control. This is the setup for most buildings and is how things have *'always been done'*.

As for DC, there is less cabling, potentially as much as 50% less, as shown by a recent DC microgrid project in the Netherlands. Control is also distributed. It can be easier to scale and add extra power because DC microgrids are typically built with a single distribution bus. In addition to using fewer materials, the greater flexibility in scaling DC, compared with AC, tends to reduce electro-magnetic interference between various equipment. Still, for some, DC may still seem like a new and intimidating setup, and many building managers want to stick with a tried-and-tested system.

The barriers to DC adoption are the lack of technical skills available, improving the safety standards by introducing fit-for-purpose regulations, and the value for money. Consequently, the lack of standards and pilot programmes directly contributes to the lack of experience and confidence.

The cost of integrating DC can be high if standalone products are purchased, as this does not consider the cost-effectiveness that comes with installing a full DC distribution system. The key to success with DC is the set-up of a holistic system that will help improve the understanding of the full benefits of adopting this approach.

When people don't fully understand the benefits, they are unlikely to invest. There is a basic level of knowledge in the market, and everyone from manufacturers to end users is accustomed to working with AC distribution even though DC is being used today in niche industries such as rail, navy, and aeronautics. Even today's legislation, regulation, and product certifications are standardized around AC.

The result? People are worried about investing in this new domain as the skills and standards are not yet mature, and installation rules require more thought as part of a holistic integration to prove cost-effectiveness.

50%

less cabling was required in a recent DC microgrid project in the Netherlands compared to AC systems.

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What should be done differently?

A hybrid approach is the way forward. AC and DC can coexist, each serving a specific purpose.

While AC is best suited for grid-powered installations, DC could add even more value in prosumer setups by efficiently integrating locally generated renewable energy and storage, thereby offering increased localized resilience against planned or unplanned disruption to the grid.

It is worth considering a local DC backbone for all renewables, which can operate in parallel to help power loads which are going to be impacted by process electrification when moving away from carbon sources to electrical power.

Long-term plans should include a mix of both AC and DC to boost energy efficiency and support onsite renewable generation.

Why is this a better way?

While AC remains a core part of energy infrastructure, DC is an all-rounder. You will use devices which are natively DC (such as computers, smartphones), and Distributed Energy Resources (DER) such as batteries and PV panels.

On the technical side, it is a lot easier to interrupt an AC current than a DC current thanks to its periodic zero crossing. For DC, traditional, conventional technology can show its limits.

DC's ability to integrate with the digital world can create a more efficient and sustainable energy landscape, accelerating the energy transition. From a safety standpoint, power electronics such as solid-state DC breakers can enhance DC protection, providing faster and more accurate fault protection compared to traditional breakers. With ultra-fast tripping features, short circuit protection occurs within microseconds, reducing the risk of damage to assets, fire due to arc flash, or even human life.

Each time we convert from one current to another, we incur energy loss. When using natural DC sources, such as photovoltaics (PV) for native DC devices, such as EV chargers, it makes sense to integrate a hybrid AC/DC microgrid.

Finally, setting up a hybrid microgrid will also reduce one unintended consequence created by our growing reliance on DC-powered devices: e-waste. According to the United Nations, 62 million tonnes of e-waste was generated in 2022, equal to the weight of 107,000 of the world's largest passenger aircraft. AC to DC converters, like phone chargers, add more potentially toxic metals and plastics into our world if these devices are not recycled properly.

What are the first steps to take?

When people recognize the benefits and understand DC, they are more likely to invest. We should upskill and educate the market, preparing for this hybrid approach, which can increase energy efficiency, evolve onsite energy infrastructure, and deliver more sustainability benefits.

To help drive further adoption, we recognize the need for new electrical standards and regulations that will spark change and open the door for innovation. There are new products such as the Active Front End (AFE) InterLink Converter — an isolated power electronic converter which joins the AC grid with the DC backbone. Distributors can get up the learning curve quickly through conducting new projects.

Our experience from one project, connected as 'loads' to the AC grid through a unidirectional InterLink Converter, has shown clear evidence of the AC grid utilities approving such project proposals quickly, cutting down waiting times from an average of two years for such renewable energy generation to be used locally.

There is a huge opportunity to solve current and future power and sustainability problems, and evolving electrical distribution is the start.

Chapter 02

Navigating AC grid congestion today

What is the market situation?

To effectively address the energy and climate crises, we must fundamentally rethink our power systems. Today, we are living in a power crisis. There is enough energy for everyone. The challenge lies in efficiently harnessing and distributing that energy to meet the power needs during specific moments in time. The solution to the power crisis lies in how supply and demand are managed.

In many countries, the grid is saturated and struggling to develop in line with electrical needs. Rolling blackouts are becoming commonplace across the world, with US states like Texas facing August blackouts due to oversubscribed energy demand. In the Netherlands, more than half of its business parks no longer have the capacity for any additional electricity consumption, while three in ten locations don't even have enough power available now. In some countries, distribution grid utilities are forcing building operators to take a separate connection for charging EVs in their car parks, as this connection can be curtailed if there is a power availability issue.

These issues are only set to continue in size and scale, and now, we are taking matters into our own hands to ensure energy security. There is enough kWh to power our EVs and our industry. But we lack kW to power everything simultaneously, or at least when people expect it.

As we move further into the Electricity 4.0 era, we will see increasingly electrified infrastructure, buildings, homes, industry, and mobility in more economically developed countries.

The new energy landscape adds rising demands for energy storage, data centers, artificial intelligence, and electric vehicles into the mix and placing an unprecedented amount of pressure on the grid. For less economically developed countries, delivering energy for all is a problem in itself, with grids still under development. Is there a way these countries can bypass the problems faced by their more developed counterparts?

As we move to an increasingly self-sufficient energy supply and adapt to a new energy landscape, renewables and prosumers will feed a bi-directional, flexible grid. A hybrid AC and DC solution will play a vital role in renewable prosumer installations for building energy efficiency and availability. The smart adoption of both currents will accelerate energy transition globally.

More than 50%

of the Netherlands' business parks no longer have capacity for additional electricity consumption.

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Why has it not been addressed yet?

The grid is struggling to meet electrical demand, and it is a long process to deliver change. The evolution of the grid is a long-term project that requires multiple stakeholder buy-in, huge investment, and a change in traditional energy infrastructure.

The congestion of distribution grids is only visible in very few countries. In other countries, power distributors either have limited preparation plans, are in the early stages of understanding the power demand issue, or are in denial. The thinktank Ember has found 11 of 26 surveyed European countries still have national transmission grid plans based on outdated wind and solar targets.

It used to be a lot easier to transmit AC with lower energy losses over long distances. But now, with diffused electrification and a move to renewables and microgrids, DC can provide a more efficient solution when the source is closer to demand. At steady-state in DC, the current simply flows through any inductor without causing any drop in voltage, and this simplifies the overall system design. Many people are unaware of the benefits of DC or are cautious about using it due to safety concerns, so uptake has been slow.

What should be done differently?

Bringing energy sources closer to home is more efficient and secure. This can remove some of the losses in electrical power transmission and distribution, which are typically between 8% and 20% depending on the country.

The IEA has recorded the growth in High Voltage Direct Current (HVDC) technology adoption which reduces power losses. Since 2010, the global length of HVDC lines has almost tripled, surpassing 100 000km by the end of 2021, with a total transmission capacity exceeding 350 GW. Yet, this represents only 2% of the total transmission length worldwide, indicating there is more room for expansion here as we find ways to accelerate the energy transition.

To ensure that all energy generation, distribution, and usage are as efficient as possible, we must prioritize the production and security of our own energy.

For everyone, electricity will move from a commodity to an asset. A move to a prosumer hybrid AC/DC installation model will make energy more flexible and sustainable, combining photovoltaics (and other renewables), energy storage (both traditional and virtual), and direct current distribution to create flexible energy nodes.

In the new energy landscape, buildings will stop being perceived as passive loads. Instead, they will become prosumers that can play a bi-directional role in the grid. This would not only boost energy security and use of renewables for the prosumer, but also benefit the grid as a whole.

Why is this a better way?

The distribution grid provides new connections only if there's enough headroom after they add up all their consumer demands. It is important to ensure consumers do get supplied up to their maximum limit. Under these circumstances, there are only a few things that the grid system operator can do during normal operation to manage the situation.

In contrast, prosumer DC installations can self-regulate, for example, following the Current/OS rules. These rules allow each equipment on the local DC installation to adjust based on a local prioritization, thereby enhancing flexibility.

DERs could add more pressure to the grids if supply and demand are misaligned. However, decentralized power and onsite energy generation can alleviate the pressure, only if self-regulation is effectively managed.

DERs allow users to reduce reliance on national power sources and increase energy resilience, and save money. For instance, by taking energy from the grid at off-peak times and using battery storage, prosumers can avoid costly peaks in demand. Such flexibility can benefit everyone — when prosumers provide power to the grid, acting as a Virtual Power Plant, or when they absorb power from a plentiful grid. On the other hand, DERs add complexity to grid management due to the intermittent nature of renewables and difficulty in accurately forecasting demand.

It is an investment (PV panels), not a consumption cost (electrical bills), and we can now monitor and manage how we use energy more effectively. This makes everyone more conscious of their usage and environmental impact, willing to make the most of their assets.

By incorporating DC into electrical installation prosumers could reduce energy loss in converting currents and reduce the complexity of adding new power to their infrastructure.

Energy is more local, sustainable, and secure as a result.

What are the first steps to take?

We must educate the market on the benefits of a hybrid approach, and the vital role of DC in electrification and energy security. Gaining experience through delivering these projects, we can demonstrate the benefits of integrating DC into building infrastructure and showcase the prosumer hybrid AC/DC installation model, increasing buy-in and investment.

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Chapter 03

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Buildings of the Future

What is the market situation?

Buildings of the future will be fully electrified, largely self-sufficient, and can accommodate an ever-increasing number of electrical devices, such as EVs, battery storage, and electric heat pumps.

Regulations such as the EU Energy Performance of Buildings Directive (EPBD) is pushing buildings towards a fully decarbonized future. However, this extra energy must come from somewhere, and the grid is already nearing saturation to cope with the demands in the new energy landscape, as seen in Texas and the Netherlands.

Managing these buildings of the future also requires a behavioral shift, and building operators should be ready to provide flexible services into the grid. From a social perspective, people should be willing to change how they charge their cars and run equipment, but it can be hard to break lifetime habits. There is also a fairness issue, as those with access to EV charging points and PV systems — whether at home or work — benefit from lower electricity costs. Meanwhile, those living in apartments, or working for employers without future-facing infrastructure, have to pay a high price for public charging and have few options to adopt renewables.

While AC power remains the dominant choice for commercial buildings, the increasing prevalence of DC-powered devices, rising utility prices, net-zero targets, and the growth of renewable energy sources like fuel cells and solar make it essential for both commercial and residential buildings to evaluate and adapt to DC where it aligns with their operations.

However, current regulations, education, and infrastructure have AC at their core, making any changes expensive and challenging.

Why has it not been addressed yet?

In most countries, there are no regulations in place for DC use in commercial buildings, such as shopping malls, office buildings, to generate their own energy, install microgrids, and operate as prosumers. It falls to the foresight of each individual business or developer to make this choice and incorporate it into their budgets.

However, finances are more squeezed than ever, and businesses have put costly infrastructure upgrades on the back burner to deal with inflationary pressures and the cost-of-living crisis.

What's more, in some countries we mentioned earlier such as the Netherlands, developers cannot get building approvals as the country's electrical distributor could not supply the energy they would require to run. This creates another barrier to progress as companies pull the plug on expansion plans and new construction projects.

What should be done differently?

Businesses should recognize that delaying improvements to electricity infrastructure could cost them more over the long term. Power management must become a priority to meet the electrical demands of building alterations, reduce electrical waste, and save on running costs.

By moving to a prosumer hybrid AC/DC installation system, commercial buildings can take a variable DC bus voltage as a control signal to coordinate all devices in the system. Each device locally monitors the DC bus voltage and its operating parameters for self-regulation, eliminating the need for centralized energy management. In other words, the control module of each device performs its own energy management rather than being controlled by a centralized system.

Adopting a prosumer installation with DC allows Current/OS' set of rules to be used. These rules can give the commercial buildings a faster way to set up a decentralized operation without communication, using DC voltage as the only coordination measure, as determined by each device. This means the control module of each device can perform its own power management including the behavioural shift that was previously highlighted. Overall system scalability and reliability also improves due to this decentralized operation.

Why is this a better way?

Commercial buildings should consider the use of DC for several reasons. DC is more energy-efficient for certain applications such as lighting, heat pumps, and elevators. Heat pumps, which are natively DC thanks to their compressor variable speed drive, do not require conversion from AC to DC, allowing for more flexible power management. Likewise, DC elevators could use the regenerative braking power rather than dispersing the energy with heat resistors, as is the case with AC elevators.

DC LED light fixtures, for instance, are highly energy-efficient because LEDs use less power and produce more light than traditional incandescent or fluorescent bulbs. DC systems also experience lower power loss, enhancing their lifespans and efficiency when compatible with renewable energy sources such as solar panels and battery storage.

Onsite renewables, such as PV and fuel cells, generate DC power. When commercial buildings use DC, they can integrate this energy into their setup more efficiently and reduce energy loss in the conversion process.

A real-life example of this is the savings Vinci Energies made when it directly powered their regional headquarters' electrical equipment through the building's PV production. Their goal was to eliminate unnecessary converters and interfaces for better energy efficiency.

The integration of DC created an estimated energy savings for Vinci Energies ranging between 20% and 30%, or a 50% reduction in the quantity of copper electrical cables required for the previous operation.

Power converters can manage or even improve power quality, and this will benefit the sensitive electronic equipment used in data centers and other critical applications. Power quality can be managed and improved by electronic converters. Furthermore, when renewables are used locally, then Transmission and Distribution (T&D) losses can be minimized.

DC reduces the risk of electrical interference and provides a more reliable power supply for critical operations, as well as combining with AC power in hybrid systems to leverage the advantages of both types of current. The N470 project, the most sustainable road in the Netherlands, is powered by a DC microgrid, and it achieve a 10% reduction on CO2 emissions compared to AC.

What are the first steps to take?

Incorporating DC as part of the hybrid approach will be vital to future-proof commercial buildings in the new energy landscape. As technology advances and more devices and systems become DC-centric, commercial buildings that embrace DC now may be better positioned for future technological developments, energy savings, and emissions reduction.

We must educate and empower property developers and building investors that integrating DC into their setup will soon become a must-have, not a nice-to-have.

Chapter 04

Renewable energy integration

What is the market situation?

According to IRENA's World Energy Transitions Outlook, renewables would comprise three-quarters of the global energy mix by 2050, with electricity becoming the main energy carrier. The agency also estimates 11 terawatts of installed renewable power capacity will be needed by 2030, requiring a tripling of renewable power and a doubling of energy efficiency. This means managing renewables and microgrids becomes a lot more challenging.

We need to generate and manage energy more effectively. Currently, DC sources such as PV must convert currents to AC to be transmitted, then convert it back to DC when entering devices. Every time the current is converted, energy is lost (8% when converting AC to DC), making the process less efficient and sustainable.

What's more, renewables are intermittent and the amount of energy they produce is largely at the will of the elements. Because of this, they require a method to balance power generation and power demand, and control battery storage to get the most from the investment. It is not as simple as buying a solar panel and installing it on your roof.

Major changes are needed to electrical installation to adapt to renewables and minimize destabilization of the grid.

Why has it not been addressed yet?

Traditionally, we have relied on the grid to generate and distribute our energy, so have little say in the process.

Now, with the rise in onsite renewables and microgrids to improve energy security, sustainability, and efficiency, we can start to look at ways to improve our own processes.

One concern is the relatively limited scale of microgrids, compared with grid-scale alternatives, may result in higher cost per unit of energy generated or stored.

Renewables are going to be a tipping point for everyone to better manage their energy. Typically, when renewable sources were installed on site, it was weaved into the existing AC infrastructure. Not only can DC be connected directly to the source, but it also helps control the power flow back and forth into the AC system with the InterLink.

Local regulatory challenges, such as meeting grid code needs, could pose a significant delay in securing planning permission, and increasing the overall cost of the project.

What should be done differently?

Put simply, we need to generate and manage electricity more effectively to keep up with the demands of electrification — and renewables are a core part of this. PV and battery storage are more affordable than ever, and we can save money and emissions by generating our own renewable power.

When we take the leap to add renewables to onsite energy production, we must also look at how we can improve energy efficiency and get the most from this greener power.

Switching to DC for PV panels and battery storage removes the energy losses from converting between AC and DC, boosting energy efficiency: research reveals LVDC systems can lower energy losses by up to 30 percent compared to AC systems, leading to significant cost and resource savings over time.

Energy supply interference to the utility provider can be reduced. If there's no need to sell flexibility services to the AC main grid, design a microgrid that can be electrically connected to the utility but without any power feed back to the grid. This is economically possible with a DC backbone and a direction-restricted interlink converter.

Alternatively, microgrids with an AC backbone tend to back-feed power to the AC grid at times of abnormalities on the AC grid side, and with any reverse power protection, this reverse power can be restricted to a time less than a few seconds. However, if there are more such microgrids in that geographical area, then that part of the AC grid may struggle to take all such back-feed, even for brief periods.

Why is this a better way?

DC is a great way to facilitate alternatives to the grid and fossil fuels. Shoring up energy supply and having access to cleaner energy are vital as we become more dependent on uninterrupted electricity.

DC is sometimes more energy-efficient than AC for certain applications, particularly in areas such as lighting and renewable energy systems. DC-powered LED lights, for example, use at least 75 percent less energy, and last up to 25 times longer, than AC-powered incandescent lighting. DC's compatibility with digital devices and systems will be a key theme in the context of the modern world and the new energy landscape.

DC power is already well-suited for the digital age, making it essential in applications involving electronics, electric vehicles, data centers, and smart grids.

What are the first steps to take?

More education with the public is required so they understand the benefits of using DC to accelerate the energy transition globally - away from carbon-based sources. DC can also improve energy efficiency in microgrids and create on-site renewable generation.

We must look to government-backed schemes to spark uptake, such as China's legislation of all new buildings having 50% of their roof covered with PV and upskill engineers that can carry out this vital work.

Beyond education, it's important for every project to firstly define the main purpose, then it makes it easier to manage costs and tariffs. Previously, the use of local diesel generators had the same challenge, but the clear purpose of using them only as stand-by to the main AC grid made them economically viable.

Looking at other options, power storage is essentially a sustainable alternative to diesel generation, while local PV or fuel cells can address the extra electricity demand (such as EV Charging), without having to increase the peak demand on the AC grid supply; so extra EV charging demand can have a different tariff which justifies the investment.

Chapter 05

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Summary

Connecting AC with DC – The future of energy transition

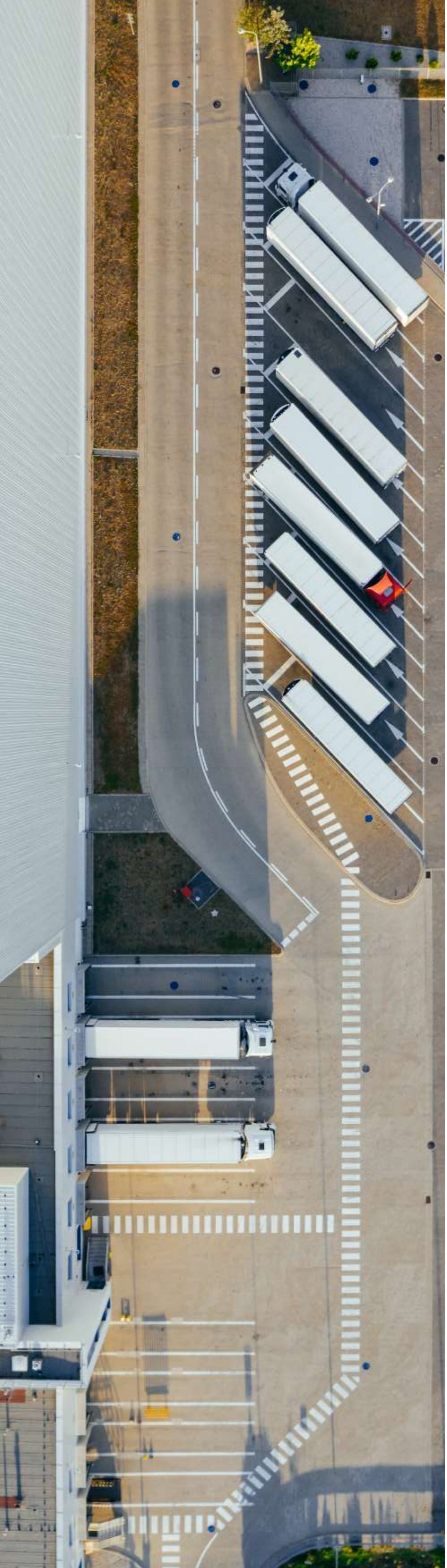
The energy landscape is undergoing a significant transformation driven by the rise of renewable energy sources and the increasing complexity of energyinfrastructure. This whitepaper explores the integration of direct current (DC) distribution alongside alternating current (AC) distribution, highlighting the potential benefits and challenges of this hybrid approach.

Today's traditional reliance on large, fossil-fuelled power stations and AC transmission is being challenged by the growth of decentralized, renewable, and local power sources. DC - already prevalent in digital devices and renewable energy systems - offers a promising evolution to the new energy landscape.

DC's ability to complement AC and support microgrids is crucial for accelerating the energy transition.

The future of energy transition lies in the coexistence of AC and DC distribution. By adopting a hybrid approach, we can enhance energy efficiency, support renewable energy integration, and create a more resilient and sustainable energy infrastructure.

Contact DC Systems for more information and to discover more about the benefits of a hybrid AC/DC installation.



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