WHITE PAPER

DIRECT CURRENT: THE SMARTER CONSUMPTION SOLUTION TO SOLVE THE ENERGY CRISIS?

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Current/OS

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About the Author

Yannick Neyret's unconventional path as a researcher-turned-intrapreneur has always driven him to push innovation forward in response to the societal challenges of electricity distribution. Now President of Current/OS and an European expert in direct current networks, this Supélec graduate has turned each of his roles within the Schneider Electric group into opportunities to explore new fields, leading him to file or c-file around fifteen patents. During the 2000s, he foresaw that electricity distribution would be the hidden challenge of the energy transition. His key focus areas are digitization, automation, and network decongestion, ensuring that everyone has access to reliable, continuous, and sustainable electricity.

About Current/OS

Current/OS is a nonprofit, open partnership of electricity stakeholders and manufacturers committed to researching and developing Direct Current (DC) power distribution for buildings and commercial installations. Our mission is to empower a sustainable future with reliable electricity access for all. Current/OS is defining the standards for Direct Current Microgrids, to ensure reliable and sustainable DC distribution, operating in a hybrid approach alongside AC from the main grids.

Executive Summary

The energy landscape is undergoing a profound transformation, driven by the increasing demands of an all-electric society and the rise of renewable and decentralized power generation. This shift has created a significant supply-demand crunch, calling for a new technological paradigm. While Alternating Current (AC) has historically shaped our electrical grid, Direct Current (DC) now dominates usage and is rapidly gaining ground in power generation. **Hybrid AC/DC microgrids are emerging as the future of energy systems**, offering a compelling solution to relieve grid congestion, ensure grid stability through enhanced control capabilities, and enable advanced features with DC products.

This is where Current/OS—a nonprofit, open partnership of electricity stakeholders and manufacturers—comes in. Current/OS is defining a distribution standard for DC to implement self-regulating, resilient power systems for buildings and installations. By fostering collaboration on DC projects within its extensive partner ecosystem, Current/OS is unlocking the full potential of DC technology, promoting interoperability, safety and simplicity in the deployment of DC microgrids and DC products. Current/OS

DC technology directly addresses the supply-demand challenge and supports the energy transition effectively.

WHITE PAPER

Direct Current: The Smarter Consumption Solution to Solve the Energy Crisis

The landscape of power generation and consumption is undergoing a rapid transformation.

On one hand, technological advancements and the increasing electrification of various sectors to support the energy transition are driving a **significant rise in electricity demand.**

In 2015, electricity accounted for 18% of final energy consumption. By 2023, this share is estimated to have reached 20%. However, to meet global decarbonization targets, the rate of electrification must accelerate significantly. According to the IEA's (International Energy Agency) Net Zero Emissions by 2050 Scenario[1]—a pathway aligned with limiting global warming to 1.5°C—electricity's share in final energy consumption needs to

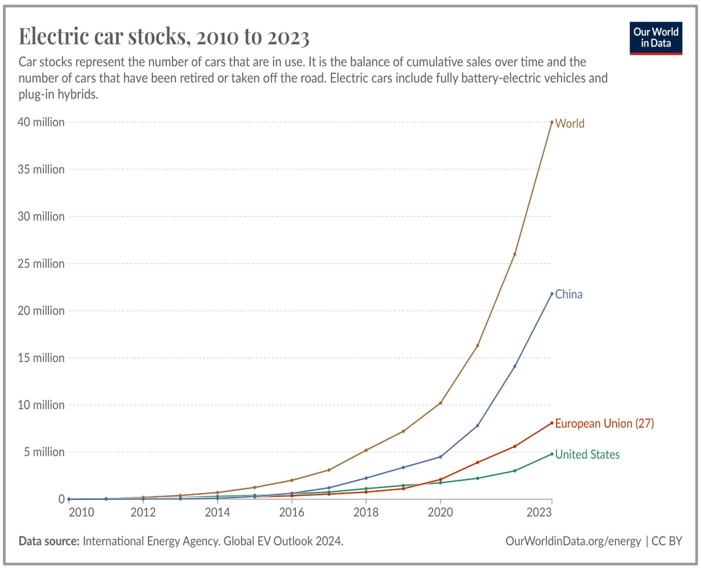
[1] https://www.iea.org/reports/net-zero-by-2050

approach 30% by 2030, and 60% by 2050.[2]

This must occur in a context wherein the adoption of renewable energy sources and the shift toward decentralized production—where energy is generated closer to the point of consumption, reducing reliance on traditional, centralized power plants—is fundamentally **reshaping the power supply.**

The pressing urgency of the energy transition away from fossil fuels and the rise of an all-electric society expose **a critical imbalance: electricity demand is escalating, while distribution networks are expanding at a much slower pace, unable to keep up**. As Eurelectric aptly states, "Connection requests are increasing faster than grid modernisation"[3], a concern that is now frequently echoed in the international press.

For instance, the number of electric cars is rapidly outnumbering power capacity forecasts. "By 2030, EVs will represent more than 60% of vehicles sold globally, and require an adequate surge in chargers installed in buildings.", notes the IEA[4] On average, EVs consume about 0.2 to 0.3 kWh per kilometer, with peak charging times posing additional strain on the grid.



Source: Virta [5]

[2] https://www.eurelectric.org/news/grid_investments_for_netzero/
[3] https://www.eurelectric.org/news/grid_investments_for_netzero/
[4] https://www.iea.org/reports/by-2030-evs-represent-more-than-60-of-vehicles-sold-globally-and-require-an-adequate-surge-in-chargers-installed-in-buildings
[5] https://www.virta.global/global-electric-vehicle-market

While many countries have set ambitious targets to phase out internal combustion engine vehicles, they invest in new grid infrastructure and time-of-use pricing strategies. However, these approaches alone may fall short: “Failure to achieve massive amounts of additional grid capacity [with new and modernized infrastructure] would jeopardize 74% of prospective connections in key decarbonisation technologies such as electric vehicles (EVs), heat pumps and renewables” writes Eurelectric.[6]

We are not just going through an energy crisis. We are experiencing **a supply and demand crunch**. **A new technological paradigm is therefore essential** to meet the growing electricity demand. This challenge goes beyond environmental and economic considerations, carrying **significant social implications** as reliable access to electricity must be ensured for everyone. In its report "Electricity for the 21st Century”[7], the International Electrotechnical Commission (IEC) states, "Direct Current is a disruptive technology that fundamentally accelerates energy access and improves energy efficiency."

Energy experts unanimously agree that **DC is the critical enabler for a successful energy transition.** Indeed, direct current (DC) has the potential to revolutionize our energy systems and consumption patterns. By enabling **smart power management at the level of a building or an installation**, it is possible to decrease **the demand for feed-in power capacity from the public grid by 2 to 5 times, without impacting the quality of life of the building’s users.**

6 https://www.eurelectric.org/news/grid_investments_for_netzero/

7 https://www.iec.ch/basecamp/lvdc-electricity-21st-century

We live in a DC world with an AC architecture

Although Direct Current (DC) was invented before Alternating Current (AC), the electrical network has evolved around AC over the past 130+ years.

Alternating Current became the standard in the late 19th century for two main reasons:

1. **Long-Distance Transmission**: Transporting DC over long distances only became feasible in the 1960s with advancements in power electronics. Large-scale deployment of DC transmission began only in the 1980s, meaning that all public electricity grids are still on AC.

2. **Industrial Use**: AC proved ideal for powering large electric motors at fixed speeds, which industries needed to replace steam engines.

Although AC infrastructure remains the norm, the **distinct advantages of DC**—such as flexibility, efficiency, and simplicity—are driving its widespread use, enabled by advancements in power electronics. While the general public may not be fully aware of this evolution, Direct Current (DC) power has now become predominant across a wide range of devices.

Telecom technologies have relied on DC for decades because it offers stable and consistent power delivery, which is crucial for the reliable operation of communication systems.

Computers, data centers, smartphones and other digital electronics—such as those found in **medical devices**—operate internally on DC, due to its more efficient and stable energy management, which enhances both performance and reliability.

LED lights and screens, which have replaced traditional fluorescent lighting in AC, are powered by DC. Their enhanced energy efficiency and longer lifespan are direct results of DC's inherent features in delivering stable and efficient power.

Electric vehicles run on Direct Current because it allows for efficient storage and discharge from their batteries, enhancing both range and performance. **Charging systems for EVs**, especially fast chargers, further leverage DC's capacity to deliver high amounts of energy quickly and safely.

Recent **A-class electric devices and appliances** rely on DC for efficient and stable operation. The internal variable-speed motors of appliances such as **refrigerators, heat pumps, washing machines, and air conditioners** operate on an internal DC bus, which is also utilized in **ceiling fans, power tools, vacuum cleaners**, and increasingly in **home automation systems** such as smart thermostats, security cameras, and even electric blinds. These devices benefit from the precision, efficiency, and reliability that DC power provides, which helps optimize their performance and energy use. More applications are expected to incorporate DC-powered motors and systems, further driving the shift towards a DC-centric energy consumption landscape.

Our electricity **consumption is increasingly shifting towards Direct Current** (DC), even as we continue to depend on an AC distribution grid to support this demand. Today, we can confidently say that we are living in a DC world, yet operating within an AC-based infrastructure

Renewables are accelerating the shift toward DC power generation

In alignment with the objectives of the European Green Deal and the global energy transition, European countries are steadily **increasing the share of renewable energy** in their energy mix. Most of these renewable sources generate power natively in DC.

Photovoltaic (PV) cells in solar panels generate DC electricity through the photovoltaic effect, where sunlight excites electrons, creating a unidirectional flow of electric charge—characteristic of DC power.

Wind turbines use DC circuits to connect to existing AC grids for transmission over certain distances to reduce losses and avoid network disruptions.

As the generation of solar and wind energy is intermittent, large-scale **energy storage systems** help maintain a stable and continuous power supply. These batteries operate in DC, storing the energy and ensuring grid stability by discharging DC electricity as needed.

France, for instance, plans to invest nearly €11 billion in offshore wind turbines over the next 20 years, and will invest a further €2.9 billion[8] in tax credits for investment in solar panels, wind turbines and batteries till the end of 2025.

In short, the energy transition is accelerating both DC generation and consumption. . Logically, connecting these DC sources and DC loads through a DC power system presents a

8 https://ec.europa.eu/commission/presscorner/detail/en/ip_24_3584

more efficient and desirable approach, rather than relying on intermediate AC conversions. At this stage, key questions arise: How would such a system interface with the AC-based main grid? And ultimately, do the benefits of DC installations justify the investment required to develop them?

Exploring the benefits of DC installations

By DC-based installations, we refer to the creation of local networks connecting DC energy sources directly to DC loads via a DC-based installation. These installations are also called DC microgrids. In reality, this is a hybrid AC/DC solution: the public grid supplies and receives power to the DC installation through AC/DC converters interfacing the DC installation with the AC grid. It is important to note that we are not referring to off-grid DC microgrids.

Let's explore the benefits of a DC installation that justify its development.

The first benefit of a DC installation is the **reduction of conversion losses** - DC/DC chains are more efficient than DC/AC to AC/DC chains. There is academic consensus, supported by numerous studies and projects, confirming this reduction in losses. This saves a statistically significant percentage (around 2 to 5%) of energy in the majority of cases; while some applications in manufacturing may see even higher gains up to 10 or 15%.

DC installations also require **less raw material** than regular installations. Power transmission in DC better uses the conducting abilities of copper cables, allowing conduction **savings of around 20%**[9]. The change in conversion standard also uses less magnetic material - DC relies on KHz power conversion as opposed to 50-60 Hz for AC[10]. However, while these

[9] Current/OS principles offer much more, but we'll leave them aside for now.

[10] Current/OS principles offer much more, but we'll leave them aside for now.

material gains are valuable, it is important to note that they require more advanced technology and do not always translate into financial savings that would alone justify the creation of DC microgrids.

DC microgrids also provide **stable, high-quality power for critical activities**. The electricity generated within these microgrids is optimally regulated, with low ripple and is free from power factor issues, typical from AC grids.

Another advantage of DC is the **ability to store excess energy** generated within the DC microgrid, either in the system's battery, an EV charger, or a water heating system for example. In an AC system, surplus energy is typically lost.

While these savings are noteworthy, one might wonder whether they are sufficient to justify the huge investments required to develop new DC microgrids and DC products. These gains may not be compelling enough to warrant such a transition.

The primary benefit of DC installations lies elsewhere. In fact, they have the potential to redefine our energy landscape: **DC microgrids reduce power calls on the main grid, and allow DC generated by local renewable energies to be smoothly injected back into the main AC grid. The peak demand for power on the main grid is greatly reduced, as are excess power returns.**

These precise power adjustments are handled by design at the equipment level. DC microgrids can **adapt their energy consumption to the available power supply, reducing demand to the grid while managing power fluctuations and surpluses from renewable generation.** By addressing these variations before they reach the main grid, DC microgrids help maintain grid stability and prevent disruptions from irregular inflows.

The unique ability of DC microgrids to reduce power calls has been demonstrated by the installation and operation of many pilot projects over several years, proving that direct current simplifies energy management.

Current/OS DC installations require 2 to 5 times[11] less feed-in power from the main grid, making optimal use of existing power delivery substations and transmission lines—directly addressing public grid congestion and instability.

In short, DC installations offer the advantage of immediate, lower-scale power availability for new projects, eliminating the need to wait for main grid capacity expansion. This is not just a "component" benefit, but a "system" benefit. **s not erratic and less. This point, which is still sometimes overlooked, is proving to**

[11] As proven by successful Current/OS DC implementations in the Circl Pavilion, a.s.r. car park or the N470 Highway for example.

be a major obstacle on the road to an all-electric society.

Our Challenge: Alleviating Grid Congestion and Ensuring Stability

As illustrated earlier, our electricity consumption is booming due to the digital and communications revolution, and the replacement of fossil-fuel-based systems with electric systems such as electric vehicles and heat pumps. The consequent **peaks in demand** require a significant increase in the public grid's capacity to deliver the additional energy.

On the renewable energy production side, commercial and residential buildings are increasingly installing photovoltaic systems to reduce energy costs and move towards NetZero. However, **renewable energy production does not align with typical buildings' consumption patterns.** For example, solar energy generation is highest during the day in spring and summer when the sun is strongest, while power demand rises in the evening for residential buildings, with a seasonal peak occurring in autumn and winter. The surplus energy produced on sunny summer days is fed abruptly into the main grid, which will struggle to absorb this intermittent influx of power. As a result, the capacity of substations and transmission lines must be overexpanded at the peak levels, and the grid must find effective ways to absorb this surplus energy to maintain its own stability.

Considerable investments are being directed toward “smart grid” technology to enhance the capacity and flexibility of the main grid, enabling it to absorb the fluctuating output from large solar and wind farms. However, **the traditional model of the grid managing peak and low demand is reaching its limits.**

The differing control capabilities of AC and DC

For AC equipment, the most common control actuators are on/off contactors, with the day/night contactors for water heaters being a well-known example. However, not all electrical equipment is designed to withstand simple on/off power switching.

Solar generation in a building fluctuates significantly, especially on partially cloudy days. A basic on/off control of the few compatible loads does not provide the necessary flexibility to match the ups and downs of solar production. As mentioned above, many A-class appliances have internal power variation systems, but these are designed to reduce energy consumption (kWh) over a cycle rather than adjust the power demand (kW) of the equipment or the building as a whole.

Locally produced energy should be consumed locally. Injecting this power into the main grid, without prioritizing local consumption is inefficient and must be addressed. Although challenging, this is a **crucial step in ensuring the success of the energy transition.**

Solar routers exist in AC systems to track PV production and adjust the power consumption of water heaters or the charging power of electric vehicles in real-time. Some can manage two load circuits. However, extending this control to all loads in a building requires an additional automation system. Current/OS has developed norms to achieve this in a simple and more efficient way with a DC installation.

To **maximize self-consumption**, precise power control for each piece of equipment is needed, coordinated automatically within the local grid.

Manually monitoring production and adjusting consumption would of course be impractical; instead **the system must be self-regulating, automatically adjusting based on power availability.**

Current/OS DC installations: resolving the supply and demand crunch

Current/OS is an nonprofit, open partnership dedicated to research and development of local Direct Current (DC) distribution. This initiative promotes electrical safety and greater energy resilience with a smoother transition to increase DC adoption in tertiary buildings and installations.

Current/OS stands for "Current-Operated System", because electricity rules the system.

In DC installations using the Current/OS solution, the voltage indicates available power, so **all devices in the system can automatically adapt their behavior in response.** Each device follows an embedded consumption or generation rule, known as the "droop curve." This droop curve is software-controlled and can be adjusted at any time.

In this setup, solar panels, EV charging stations, LED lighting, electronics, and various other loads across the installation operate together seamlessly, **adapting dynamically to power availability.**

The voltage fluctuates based on the collective contributions and consumption within the power system. Unlike in AC systems, voltage is not controlled by a single leading power source.

This autonomous electricity consumption is only possible with Direct Current, known for its flexibility, precision and storage capacity.

This distributed control approach across DC microgrid devices offers key advantages that are critical for the transition to DC microgrids:

1. **Reduced demand from the main grid**: Current/OS-based DC installations have demonstrated a reduction in power demand to the public grid by 2 to 5 times. This significantly limits network congestion and can result in substantial savings on grid expansion investments. It allows more buildings to be built and connected to the main grid.

2. **Resilience**: Compared with other forms of microgrids, the system is highly resilient to failures. Each DC device and appliance autonomously regulates its energy consumption based on the available power in the DC microgrid. If one piece of equipment fails for any reason, the system remains unaffected and continues to balance itself. The absence of central control reduces the risk of outages and enhances overall reliability.

3. **Scalability**: Expanding DC installations is straightforward for any professional electrician. It's simple to install and requires no automation or IT skills. Adding new equipment is simple, the system naturally finds its equilibrium. Unlike centralized automation systems that require coordinated updates, this approach eliminates a major pain point for integrators.

Overall, the Current/OS approach offers a robust, flexible, and scalable solution to the challenges facing the public grid and modern energy systems, while allowing project promoters to build without waiting for the grid's capacity to be extended.

A DC installation using Current/OS electric rules is therefore able to escape the supply and demand crunch.

Conclusion

Current/OS offers a transformative approach to significantly reducing the power demand and surges of buildings, maximizing the use of renewable energy—without overloading or destabilizing public grids.

By enabling seamless coordination between devices within the system, DC microgrids based on the Current/OS solution optimize the use of locally generated renewable energy while reducing grid congestion and enhancing the public power system stability.

This innovative framework not only enhances energy efficiency but also accelerates the energy transition by facilitating the **widespread adoption of renewable energy** and **reducing buildings' energy power demand**—all while preserving grid integrity and avoiding the need for exponential expansion of existing public electrical infrastructure.

To learn more or explore joining the partnership, we encourage you to reach out to the Current/OS team.