DC MICROGRIDS FOR INDUSTRY AND LOW POWER CHARGING INFRASTRUCTURE

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Abstract

In recent years, DC microgrids have gained increasing relevance across several application domains, including industrial environments, DC data center infrastructure, and fast-charging systems. This paper provides an overview of the current state of the art in industrial DC grid technologies and low-power DC charging infrastructure, drawing on recent research activities at Silicon Austria Labs. The work highlights the key advantages of DC microgrids while addressing several associated challenges, particularly in the areas of protection, useable converter topologies, concepts, coordination, and system stability.

State of the art

Several research projects - particularly the DC-Industry and DC-Industry 2 initiatives - have demonstrated key advantages of DC microgrids. These efforts resulted in a comprehensive system description presented in [1], showing that DC microgrids offer several benefits compared to conventional AC grids [2], including:

- Reduced copper cabling requirements and lower cable losses
- Decreased overall energy consumption and the ability to recover braking energy
- Direct and efficient integration of renewable energy systems
- Increased system availability due to fewer energy conversion stages and, consequently, fewer components that may fail
- Lower infeed power and reduced peak power demand through the integration of battery energy storage systems

Despite their advantages, DC microgrids have several drawbacks. Protection and fault interruption are challenging due to the lack of natural current zero crossings, requiring advanced devices such as solid-state circuit breakers. Initial costs can be higher because of specialized converters and protection equipment. While standardization exists, it often needs adaptation for DC technology. Integration with AC systems can be complex, and the overall deployment of DC microgrids is limited by the relatively low experience of planners and companies, as well as the limited availability of DC-specific products.

DC microgrid for industry

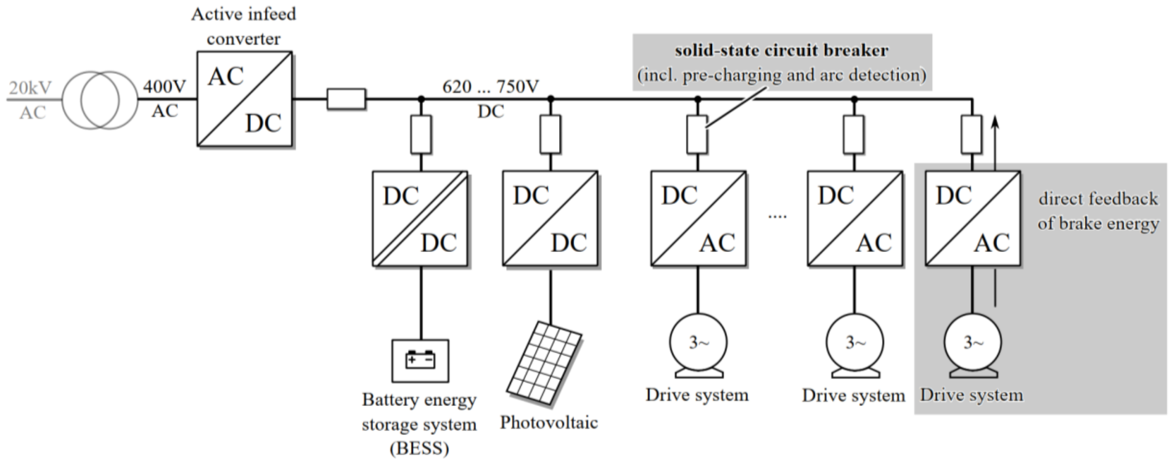

Figure 1: Example of an industrial DC microgrid with main infeed converters and loads.

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An industrial microgrid is shown in Figure 1. Most industrial loads consist of machinery and rotating equipment. By avoiding the typically required AC–DC conversion stage, braking energy can be fed directly back into the DC bus. Furthermore, losses in DC–DC conversion are lower than in AC–DC conversion, and the infeed converter can operate at more favorable load points, improving overall efficiency. The DC bus voltage is regulated collectively by all connected converters using droop control [1]. A key challenge in DC microgrids is the protection and rapid interruption of short-circuit currents, as well as the detection of arcs. Unlike AC systems, where current naturally passes through zero, DC faults do not self-extinguish, making conventional protection methods ineffective. These issues can only be effectively managed using solid-state circuit breakers.

DC-microgrid for low power charging

An example of a DC charging infrastructure is shown in Figure 2. In the future, DC charging systems may become a viable alternative to the currently established AC charging infrastructure. Today, AC chargers rely on the onboard charger integrated into electric vehicles, and the costs are typically borne by the vehicle owners. However, future vehicle designs may no longer require onboard chargers if a sufficiently dense low-power DC charging infrastructure becomes available, with the associated costs covered by the infrastructure owner. Such infrastructure could be deployed at supermarkets, commercial areas, or large parking facilities.

To minimize hardware costs, one option is to implement power-sharing strategies, allowing the available charging power to be distributed among multiple vehicles when more than one car is connected to the charger.

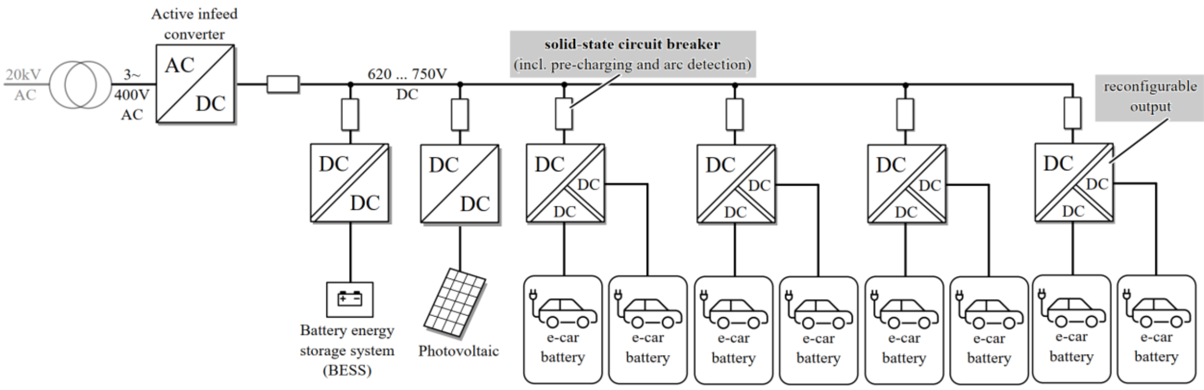

Figure 2: Example of a DC charging infrastructure for electric cars.

Conclusion

DC microgrids are increasingly proving to be a viable solution for industrial applications and in future for low-power charging infrastructure as well, with several pilot plants already demonstrating their practical feasibility [3]. These systems offer clear advantages over traditional AC setups, including improved energy efficiency, reduced conversion losses, and better integration of renewable energy sources. While pilot implementations confirm these benefits, certain aspects - particularly protection, rapid short-circuit interruption, arc detection, and the optimization of converter topologies for specific applications - still require attention. Although effective solutions exist, further optimization and practical testing are necessary to fully integrate them into industrial and public DC microgrid infrastructures. These open questions are being actively investigated in the research projects at Silicon Austria Labs mentioned and will be discussed in detail in the full paper version.

Referenzen

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