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Editorial

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Hybrid AC/DC Microgrids: Enhancing Flexibility and Efficiency in Modern Power Systems

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Introduction

The increasing integration of distributed energy resources (DERs), such as solar photovoltaic (PV) panels, wind turbines, and battery storage, has transformed conventional power networks. Traditional alternating current (AC) microgrids are effective for standard energy delivery, while direct current (DC) microgrids are ideal for renewable sources and DC loads, including data centers and electric vehicles. Hybrid AC/DC microgrids combine the advantages of both AC and DC systems, providing a flexible, resilient, and energy-efficient solution for modern power networks. They are particularly valuable in applications requiring high reliability, renewable integration, and optimized energy management [1,2].

Discussion

Hybrid AC/DC microgrids integrate AC and DC subsystems through bidirectional converters, allowing seamless power flow between AC and DC domains. This configuration supports a wide range of generation sources, energy storage devices, and load types. For instance, PV arrays, fuel cells, and batteries naturally operate in DC, while conventional motors and household appliances use AC. By directly connecting DC sources and loads, hybrid microgrids reduce unnecessary AC/DC conversion losses, improving overall system efficiency [3,4].

Energy management is a critical aspect of hybrid microgrids. Advanced control strategies monitor generation, storage, and load demands in real time, coordinating power flow to optimize efficiency and reliability. Energy can be prioritized based on source availability, storage state-of-charge, and load criticality. Predictive algorithms can anticipate renewable generation fluctuations or load variations, enabling preemptive adjustments that enhance stability and reduce reliance on backup sources [5].

Hybrid AC/DC microgrids also improve system resilience. Bidirectional converters and distributed control architectures allow microgrids to operate autonomously during grid outages, maintaining uninterrupted power supply for critical loads. Fault isolation, load sharing, and adaptive reconfiguration further enhance reliability, making hybrid microgrids suitable for hospitals, military bases, campuses, and industrial facilities.

The hybrid approach also facilitates renewable integration and sustainability. By efficiently managing AC and DC power flows, the microgrid can accommodate variable renewable generation, minimize energy losses, and reduce greenhouse gas emissions. Additionally, the ability to connect with electric vehicle charging stations, smart appliances, and energy storage systems makes hybrid microgrids a cornerstone of smart and sustainable urban energy infrastructure.

Challenges remain, including the complexity of control algorithms, converter sizing, protection coordination, and cost management. Ongoing research focuses on standardized architectures, robust control schemes, and intelligent energy management systems to address these issues.

Conclusion

Hybrid AC/DC microgrids combine the strengths of AC and DC systems to create flexible, efficient, and resilient power networks. By enabling seamless integration of renewable sources, diverse loads, and energy storage, they enhance energy efficiency, reliability, and sustainability. As distributed generation and smart energy systems continue to expand, hybrid microgrids will play a vital role in shaping the future of modern, adaptive, and low-carbon power infrastructure.

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