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Shipboard DC Systems—A Critical Overview: Challenges in Primary Distribution, Power-Electronics-Based Protection, and Power Scalability

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ABSTRACT This article gives an overview of challenges in primary distribution, protection, and power scalability for shipboard dc systems. Given that dc technology is in development, several aspects of shipboard systems have not yet been sufficiently devised to ensure the protection and efficiency demanded. Several issues in dc systems arise from the lack of complete relevant standardization from different regulation bodies. Unipolar and bipolar bus architectures have application-specific advantages that are discussed and compared. The placement of power electronics in dc systems creates opportunities for switchboard design, and this article compares the centralized and distributed approaches. Likewise, protection architectures for shipboard dc systems have challenges. Breaker-based protection utilizes slow fuses, mechanical circuit breakers, and solid-state circuit breakers. In addition, power-electronics-based protection embeds the protective circuit in the power converters, but its development lags. This article compares the state-of-the-art technologies, reviewing their main features. Finally, the power requirement of various applications and the low production rate of vessels force the designers to utilize commercial off-the-shelf converters to scale up power. The misuse of such converters, the modular topologies, and power electronics building blocks are exposed highlighting challenges and opportunities toward the mass adoption of dc systems onboard maritime vessels.

INDEX TERMS DC circuit breakers, dc systems, power-electronics-based protection, power electronics building blocks (PEBBs), power scalability, shipboard dc systems.

NOMENCLATURE

APU	Auxiliary power unit.
COTS	Commercial off-the-shelf.
DAB	Dual-active bridge converter.
EP	Electrical propulsion.
ESS	Energy storage system.
HCB	Hybrid circuit breaker.
HP	Hybrid propulsion.
ICE	Internal combustion engine.
IGBT	Insulated gate bipolar transistor.
IGCT	Integrated gate-commutated thyristor.

JFET	Junction-gate field-effect transistor.
LVDC	Low voltage direct current.
MCB	Mechanical circuit breaker.
MMC	Modular multilevel converter.
MOSFET	Metal-oxide-semiconductor field-effect transistor.
MOV	Metal-oxide varistor.
MP	Mechanical propulsion.
MVDC	Medium voltage direct current.
SSCB	Solid-state circuit breaker.
TRL	Technology readiness level.

Shipboard Power Protection Solution Overview

Dac-Nhuong Le, Abhishek Dhar, Ranjan Kumar, Saravanan Muthaiyah, Saurabh Adhikari

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