Modular Multilevel Converters

MODULAR multilevel converters (MMCs) have emerged as an attractive solution for high-voltage high-power applications, such as high-voltage direct current (HVdc) transmission systems, due to their attractive features such as modularity, reliability, high voltage capability, and small footprint. However, new power converter topologies and recent advances in terms of control have expanded the application of the MMC to power conditioning and machine drives, among others.

This special issue is focused on the latest achievements on MMCs regarding the development of new circuit topologies, modeling, operation, and fault analysis.

Examples of new applications of the MMC are the development of a high-voltage pulse generator in which the high voltage capability of the MMC is employed [item 1) in the Appendix], and a dc–dc converter based on a push–pull configuration in which the diodes are replaced by MMC arms [item 2) in the Appendix]. Modifications of the original topology have also been proposed to address different disadvantages of the MMC such as a delta interconnection of arms to operate at zero frequency [item 3) in the Appendix], a three-terminal central submodule to reduce the capacitor voltage ripple [item 4) in the Appendix], and a chain-link configuration of submodules to achieve a low step-up dc–dc converter [item 5) in the Appendix].

Due to the complexities of the MMC model, a small-signal alternative is commonly used. In [item 6) in the Appendix], a small-signal model is introduced to obtain an HVdc grid model, and to analyze the dynamical behavior under unbalanced grids [item 7) in the Appendix].

The circulating current is still an issue in these converters, whose current reference can be studied and optimized for different control purposes [item 8) in the Appendix]. The output voltage can present an error in terms of amplitude and phase which, depending on the control strategy applied, can be reduced [item 9) in the Appendix]. Several structures of the MMC have been proposed in the literature, where the most common ones are compared, particularly for negative sequence operation [item10) in the Appendix]. Although the efficiency of these converters is high, a detailed analysis and modeling is still required in order to determine a proper cooling system. The simplicity of these models is one of the key elements in this regard [items 11) and 12) in the Appendix].

The design of the MMC in terms of reliability and cost is addressed in [item 13) in the Appendix].

Several control contributions are also covered in this special issue. For instance, the integration of the MMC with machine drives and its associated control scheme [item 14) in the Appendix], the control of the arm voltage imposing zero current switching in the alternate arm converter [item 15) in the Appendix], and the control strategy that increases the power-transfer capability and at the same time reduces the ac circulating current in a dc–dc MMC [item 16) in the Appendix]. Discontinuous modulation is implemented in an MMC-based motor drive system in [item 17) in the Appendix]. For proper operation of the converter, a new energy controller is presented, which is suitable for operation with nonsinusoidal reference signals.

Balancing the capacitor voltages still has room for improvement, particularly in terms of computational efficiency, which can be addressed using a proper modulation technique [item 18) in the Appendix].

Predictive control methods are very challenging when applied to the MMC. In this special issue, the approach in [item 19) in the Appendix] is based on a modulated predictive control, while [item 20) in the Appendix] presents a two-stage predictive control. In [item 21) in the Appendix], a fast closed-loop control method based on optimized pulse patterns is proposed. It is combined with a fast-acting dead-beat circulating current controller and linked to an upper layer voltage balancing control scheme. Two capacitor voltage balancing strategies for MMCs based on model predictive control are presented in [item 22) in the Appendix].

Operation of the MMC under faults is analyzed in [item 23) in the Appendix], particularly for phase-to-ground faults. Fault-tolerant operation of the MMC is achieved by bypassing submodules and modifying the modulation technique using the dc and neutral-point shift strategy [item 24) in the Appendix], and also with space-vector modulation [item 25) in the Appendix].

Another alternative to operate the MMC under faults is based on applying the neutral-point shift strategy but based on a thermal control [item 26) in the Appendix].

We hope this special issue will be useful as a reference for the research of MMCs.

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Appendix
Related Work

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