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| **Abstract:** |  |
| The adoption of High Voltage Direct Current (HVDC) systems based on Modular Multilevel Converters (MMC) has grown significantly due to their modularity, scalability, and superior output voltage characteristics. Unlike traditional Voltage Source Converters (VSC) technology, MMC systems are unaffected by the characteristics of the connected AC power, allowing for greater flexibility in power network configurations. This article establishes a theoretical framework for MMC-HVDC systems, detailing the fundamental principles and mathematical models that govern their operation, along with control systems, harmonic analysis, specialized power system applications, and protection systems. The dynamic responses of system parameters are analyzed concerning inherent characteristics and operational constraints, with values systematically designed based on desired objectives. Additionally, with an active power of 1000 MW, the system exhibits nominal voltage values of 400 kV on the primary and 333 kV on the secondary side. The paper introduces a model to validate operational concepts and assess dynamics of the proposed system under various conditions, including steady-state, transient response, voltage, current regulation, active and reactive power. It also presents an innovative method that increases arm inductance to reduce Total Harmonic Distortion (THD) in arm currents. A key finding is the simultaneous adjustment of arm inductance (14 p.u.) and submodule (SM) capacitance (5.757 mF), which identifies an optimal condition resulting in the lowest THD (1.63%).  This reduction in THD enhances power quality by minimizing harmonic distortions. The performance optimization provides valuable insights into the dynamic behavior and performance metrics of the system, offering critical assessments and strategies that can aid researchers and engineers in addressing challenges associated with MMC-HVDC systems, ultimately promoting their broader integration into smart grid infrastructures. | |