Abstract

Mahmoud O El Wadee

CAPACITOR VOLTAGE BALANCING, FAULT DETECTION, and FAULT TOLERANT CONTROL TECHNIQUES OF MODULAR MULTILELEVEL CONVERTERS

Modular Multilevel Converters (MMCs) are distinguished by their modular nature that makes them suitable for wide range of high power and high voltage applications. However, they are vulnerable to internal faults because of the large number of series connected Sub-Modules. Additionally, it is highly recommended not to block the converter even if it is subjected to internal faults to secure the supply, to increase the reliability of the system and prevent unscheduled maintenance. This thesis introduces a fault tolerant control system for controlling the MMC in normal as well as abnormal operating conditions. This is done through developing a new adaptive voltage balancing strategy based on capacitor voltage estimation utilizing ADAptive LInear NEuron (ADALINE) and Recursive Least Squares (RLS) algorithms. The capacitor voltage balancing techniques that have been proposed in literature are based on measuring the capacitor voltage of each sub-module. On contrary, the proposed strategy eliminates the need of these measurements and associated communication links with the central controller. Furthermore, the thesis presents a novel fault diagnosis algorithm using the estimated capacitor voltages which are utilized to detect and localize different types of sub-module faults. The proposed fault diagnosis algorithm surpasses the methods presented in literature by its fast fault detection capability without the need of any extra sensing elements special power circuit. Finally, a new Fault Tolerant Control Unit (FTCU) is proposed to tolerate the faults located inside the MMC submodules. The proposed FTCU is based on a sorting algorithm which modifies the parameters of the voltage balancing technique in an adaptive manner to overcome the reduction of the active submodules and secure the MMC operation without the need of full shut-down. Most of fault tolerant strategies that have been proposed by other researchers are based on using redundant components, while the proposed FTCU does not need any extra components. The dynamic performance of the proposed strategy is investigated, using PSCAD/EMTDC simulations and hardware in the loop (HIL) real-time simulations, under different normal and faulty operating conditions. The accuracy and the time response of the proposed fault detection and tolerant control units result in stabilizing the operation of the MMC under different types of faults. Consequently, the proposed integrated control strategy improves the reliability of the MMC.