Abstract of Ph.D. Thesis

"Design and Implementation of High Power Converters for Medium Voltage Induction Motor Drives"

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ABSTRACT

This thesis work deals with the design and development of high-performance medium voltage induction motor drive systems for the variable speed operation so that these drive systems can be effectively utilized for the various applications of industries. Initially, this work develops various multi-pulse AC-DC converters to overcome the challenges and mitigate the harmonics components at the grid end of the drive system. In this work, the winding arrangement of the transformers are comprehensively analyzed, and accordingly, different techniques like phase displacement and multi-phase conversion are presented for developing various AC-DC converters. Few of the grid side converters (18-pulse, 30-pulse, 36-pulse, and 54-pulse AC-DC converters) are designed and implemented with single unit of the multi winding transformer. Phase displacement technique has been implemented among the secondary windings of transformers to develop these 18-pulse, 30-pulse, 36-pulse, and 54-pulse AC-DC converters. Although these power converters adhere to the power quality successfully at the grid end but the manufacturing of the transformer units for these converters becomes complex due to very small phase displacement among the secondary windings. Consequently, multi-unit multi-winding transform architectures are developed in this research work. Here, these multi winding transformers are designed for 24-pulse, 36-pulse, and 54-pulse AC-DC converters. The phase displacement technique is implemented not only secondary winding as well in primary windings also. Due to this, the windings of transformers are designed with a large phase displacement angle, which overcomes the manufacturing challenges of the transformer unit for higher pulse converter. Three–phase system based 36-pulse and 54-pulse AC-DC converters significantly impact power quality of those drive systems, which have utilized high levels of multilevel inverters like symmetric/asymmetric 7-level, 9-level….N-level. Another major issue of power quality occurs when drive systems are designed with 3-level or 4-level inverter configurations. Hence, a high pulse converter is required to sustain the power quality standard of a medium-voltage system when a drive operates with a low-level inverter. Therefore, this research works focuses on developing a high–pulse converter (30-pulse, 50-pulse and 60-pulse AC-DC converter) by implementing multi-phase conversion as well as phase displacement technique on multi winding transformer. Further, this work does not focus only on the grid side as well as it focuses on drive-side challenges also. In this research work, conventional cascaded H-bridge 5-level, 7-level, 13-level symmetric as well as asymmetric configuration is presented. The structure conventional H-bridge requires huge number of sources, to reduces the number of sources multi-level inverter configurations designed with different type circuit arrangement among the isolated and non-isolated leg based two-level inverter. Through these circuit arrangements, 4-level, 5-level, 6-level, and 7-level inverter structures are developed. Apart from this, to overcome the number of components at the drive side converters, novel inverters configurations are designed with the cascaded arrangement of the unit cell and h-bridge. The symmetric and asymmetric reduced switches based multi-level inverter structure are designed for developing 5-level,7-level,9-level, and 11-level inverter. In the last, hybrid configurations of multi-level inverter are also designed. After effectively developing the various power converter for both end of the drive system, this research work deals with the modulation technique to operates the drive side converter effectively for make variable speed operation and high-power quality performance. This research work presents modified level shifted pulse width modulation, flag type-pulse width modulation and carrier overlapped pulse width modulation for 4-level, 5-level, 6-level and maximum 7-level inverter. Moreover, fundamental switching frequency based selective harmonic elimination, nearest level control and area equalization modulations technique are presented for higher level inverters like 7-level, 9-level, 11-level, 13-level inverters. Notably, all the proposed power converters based medium voltage induction motor drive configurations are designed and developed to realize improved power quality performance at the supply side as well as drive side and strictly comply with set national/international standards while operating under defined operating conditions. Each medium voltage induction motor drive configuration's operational analysis, design, and control are analyzed comprehensively, considering wide operating conditions. The performance of the presented configurations of medium voltage induction motor drive configuration's and the associated control techniques is analyzed by performing simulation on MATLAB/Simulink platform. Additionally, the laboratory prototype of the system undergoes an experimental validation of all the described topologies, and the corresponding test results are reported.